Resistance and Acquiescence to Stupendous Geologic Erosion, Green Valley, Trans-Pecos Texas

Professional Soil Scientists Association of Texas
Ecological Site and Soil Science Field Tour
Alpine, Texas
August 5, 2017

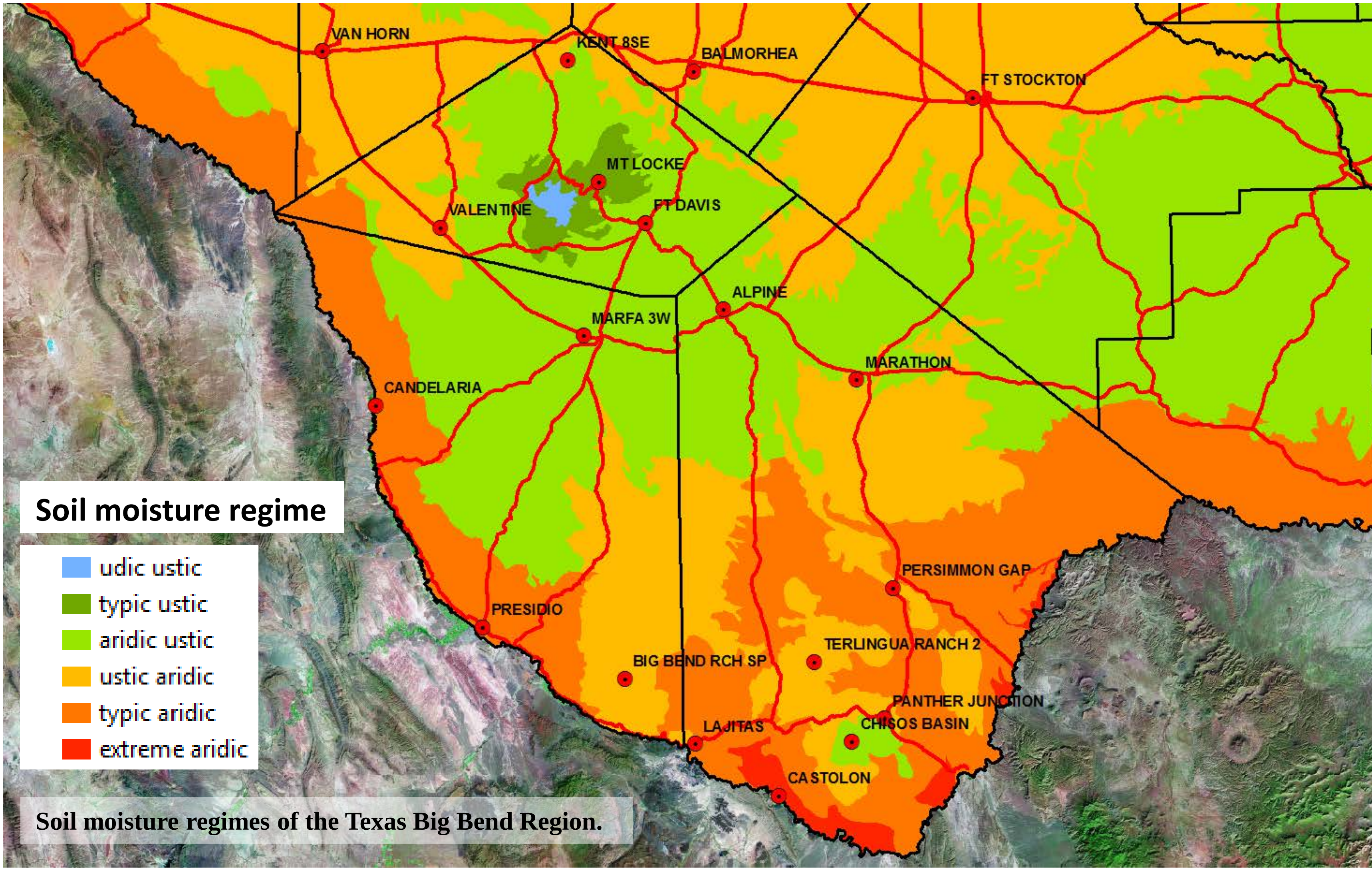
In studying the geology of the Chisos country, one must constantly bear in mind that the terranes which we now find exposed at the surface have been laid bare from under a covering of overlying rocks measuring from two to ten thousand feet in depth. This great thickness of vanished strata has been removed during a long lapse of time, which commenced with the closing stage of the Cretaceous age. We should also remember that during the time this work of disintegration and removal was going on, and even before it began, the whole ground has been subjected to forces which have thrown the strata into folds and flexures and broken them by great faults into blocks that are extensively tilted.

Johan August Udden. 1907. A Sketch of the Geology of the Chisos Country, Brewster County, Texas. University of Texas Bulletin 93. 101 pp.

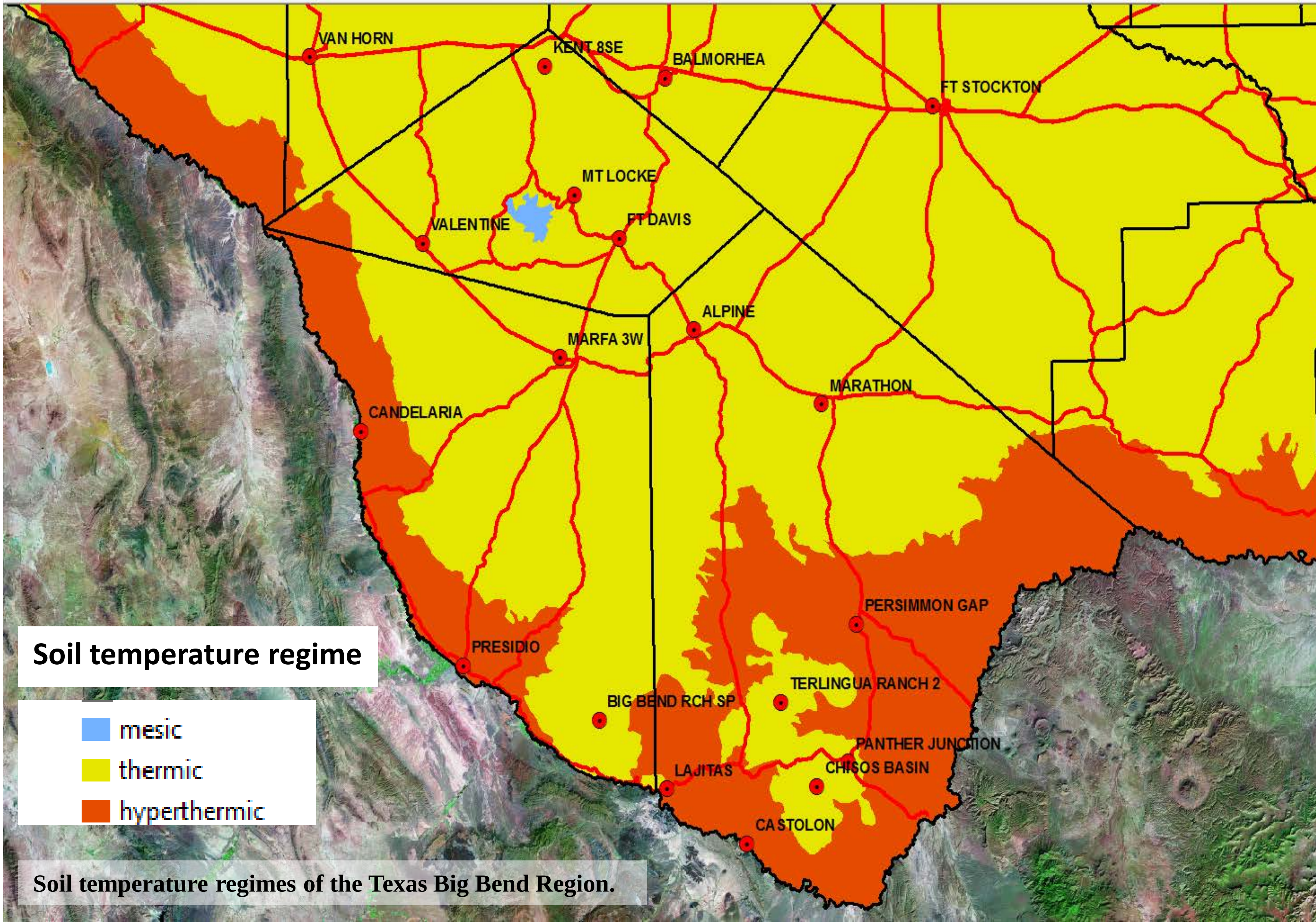
Cover photo: Geomorphic evidence of stupendous geologic erosion in Green Valley. In middle ground is Straddlebug Mountain, a prominent landmark within Green Valley. On the southeastern skyline is Nine Point Mesa, and the mid-Pleistocene age Green Valley Ranch pediment surface is in the foreground.

Evidence: The Oligocene-age intrusive syenite at the summit of Straddlebug Mountain is 97 meters (318 feet) above the channel of Terlingua Creek. The 360 meters (1,181 feet) thick Eocene-age intrusive sill capping Ninepoint Mesa rests 646 meters (2,119 feet) above the current drainage network. The Green Valley Ranch pediment is 17 meters (56 feet) above the level of Terlingua Creek.

Interpretation: Intrusive rocks cooled in the subsurface, below a roofrock mantle of unknown thickness. Since the Eocene-age intrusion of the Nine Point Mesa sill (56 to 34 Ma), almost 650 meters (2,135 feet) of erosion has taken place. After emplacement of the Straddlebug Mountain plug during the Oligocene-age (34 to 23 Ma), nearly 100 meters (328 feet) of erosion has occurred. Terlingua Creek has incised nearly 20 meters (66 feet) following development of the Green Valley Ranch geomorphic surface during the mid-Pleistocene-age.



Soil moisture regimes of the Texas Big Bend Region.



Soil temperature regimes of the Texas Big Bend Region.

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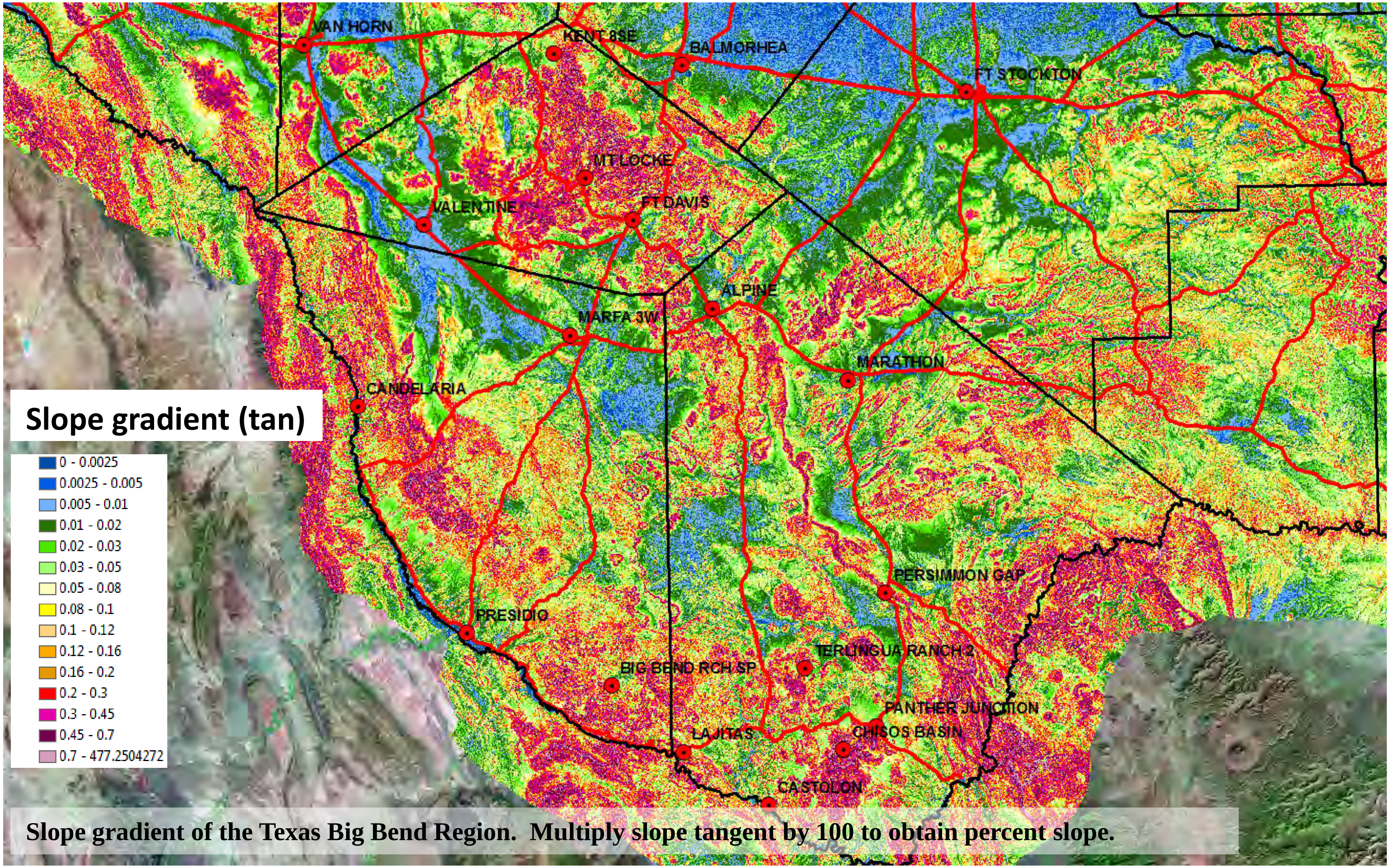

Slope gradient of the Texas Big Bend Region. Multiply slope tangent by 100 to obtain percent slope.

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Welcome to Far West Texas and the 2017 PSSAT Field Tour! Texas is a state vast in its natural resources, with soils and climate as diverse as our people. The Chihuahuan Desert of Trans-Pecos Texas is an especially diverse ecoregion with much to offer the inquisitive ecologist, geologist, or pedologist.

I wish to acknowledge and thank several partners for their integral roles in the development and success of this field tour. Special thanks to Lykes Bros Inc., for welcoming PSSAT to the O2 Ranch and for providing a backhoe with operator to open soil pits. The USDA Natural Resources Conservation Service for much of the research and publication of this guidebook. Sul Ross State University College of Agriculture and Natural Resources for sharing ongoing research efforts and for the generous donation of transportation during the field tour. The Center for Big Bend Studies for sharing their archaeological research with our group.

This field tour is the telling of a story over twenty years in the making. The unique soils of Green Valley were inventoried by Dr. Lynn Loomis as a Field Soil Scientist for the USDA-Soil Conservation Service in the 1990s. This soil survey has served as a guiding tool for rangeland planning and restoration efforts conducted by the O2 Ranch and ongoing research conducted by Sul Ross State University.

This story has been dutifully woven together by Dr. Loomis, but the story goes back much further as our current understanding rests on the shoulders of the eminent geologists and range ecologists of previous generations. Future work will build upon this current representation of field evidence and interpretations. The material presented is intended to stoke discussion and argument. Discussion builds understanding and argument builds further research questions (and we all know that pedologists enjoy a good argument.) So pull out your pedologist hat and let's all enjoy ourselves!

Cheers,
Chance Robinson
PSSAT President

Center for Big Bend Studies

Acknowledgements

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Charles Lykes
Homer Mills
John Tallent

Sul Ross State University Faculty and Students

Chris Jackson
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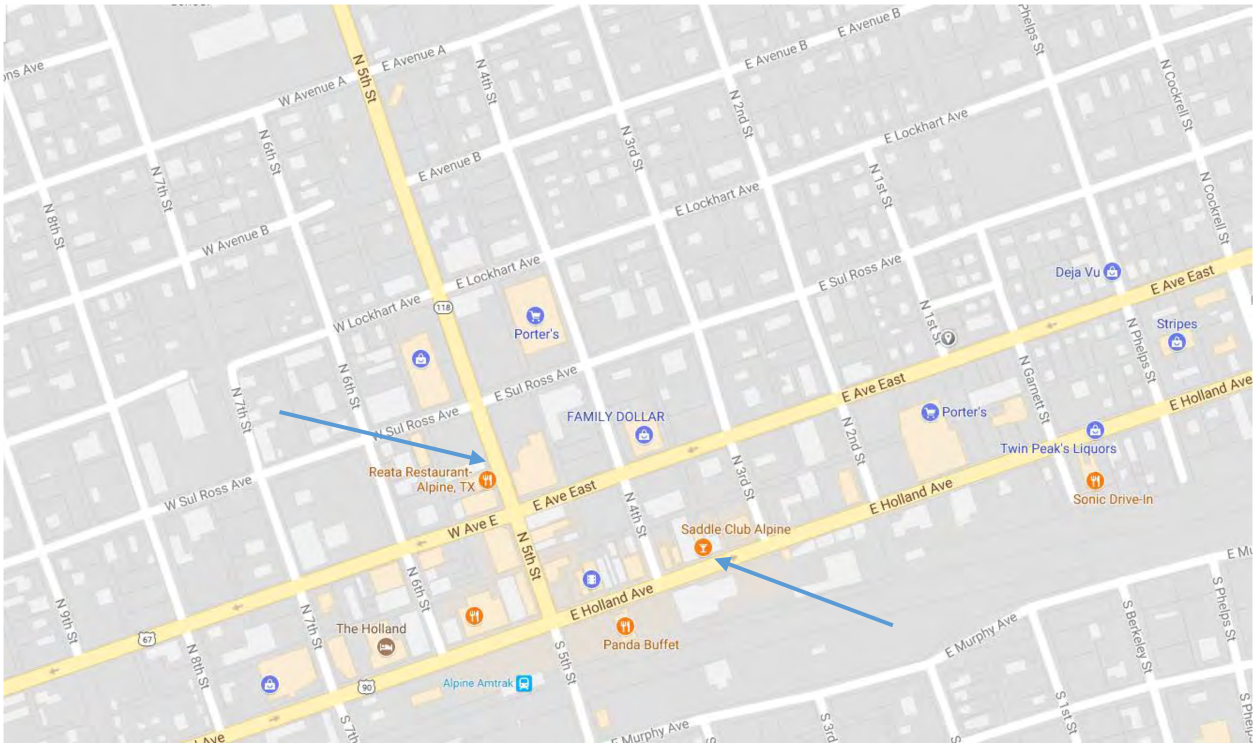
Bonnie Warnock

Schedule

Date	Time	Event
Friday, August 4	6pm - 9pm	Presentations and Dinner at The Saddle Club, 211 E Holland Ave, Alpine, Texas
Saturday, August 5	7am - 5pm	Field Tour at O2 Ranch, Green Valley, Trans-Pecos, Texas
Saturday, August 5	7pm	Social/Mixer and Dinner at Reata Restaurant, 203 N 5th St, Alpine, Texas



Map of Alpine showing locations of the Reata Restaurant and the Saddle Club.


Reata Restaurant, Alpine, Texas

Saddle Club, Alpine, Texas

Introduction to the O2 Ranch

In the late 1880s, one of the largest cattle operations in the Trans-Pecos region of West Texas belonged to E.L. Gage. Gage registered the O2 brand in 1888. In 1891 William Turney, an area attorney and cattleman, bought the O2 brand from Gage and began buying the land that now constitutes the O2 Ranch. By the 1930s he had put together virtually the entire ranch as we see it today.

Lykes Brothers purchased the O2 Ranch in 1941. It currently aggregates about 272,000 acres. The ranch lies within the Chihuahuan Desert. In its native condition, it's largely composed of grasslands and rocky outcrops. Lykes Brothers ran its own cattle operation on the O2 until 1965 and subsequently leased the ranch for others to graze and hunt. In 1998, they withdrew the ranch from grazing to begin a long-term program to restore the land to its native condition and focus on wildlife management.

Over the years, Charles P. Lykes Jr. and ranch operator Homer Mills have partnered with Sul Ross State University, Natural Resource Conservation Service, Texas Parks and Wildlife Department, and U.S. Fish and Wildlife Service to protect, restore and monitor riparian areas and associated uplands. Treatment of 4,000 acres of shrub-encroached land provides crucial habitat for grassland species such as prairie dogs, pronghorn, and burrowing owls. Committed to education and research, the O2 supports numerous research studies and hosts field tours for students, resource professionals, and landowners. In 2011, Lykes was honored by TPWD as the Lone Star Land Steward for the Trans-Pecos Ecoregion for its "... dedicated stewardship of the land through excellence in wildlife habitat management."

Climate of Green Valley

The climate of the Brewster-Jeff Davis-Presidio County area is continental arid and semi-arid. Summers are hot and winters are cool. Though winter days are warm, freezing temperatures occur most nights. Precipitation is limited and falls mostly during the warm season; plants must tolerate long periods of dry soil conditions.

Four cooperative meteorological observation stations (Alpine, Marathon, Big Bend Ranch State Park, and Persimmon Gap) with long-term records occur in or near the tour area (Figure 1 and Table 1). Henry Fletcher recorded temperature and precipitation at the O2 Ranch Headquarters from 1914 to 1928, but no cooperative weather observations have recently been recorded in Green Valley.

Of the four stations, Persimmon Gap at 873 meters (2,865 feet) elevation has the hottest, driest climate. Mean annual air temperature (MAAT) is 19.9 C (67.8 F) results in 1,077 millimeters (42.40 inches) of potential evapo-transpiration (pET). The mean annual precipitation (MAP) of 289 millimeters (11.39 inches) is 789 millimeters (31.06 inches) short of meeting evaporative demand (annual water deficit [AWD]). The Hot Desert Shrub Ecological Zone has a typic aridic soil moisture regime and marginal hyperthermic soil temperature regime.

Big Bend Ranch State Park at 1,265 meters elevation (4,150 feet) represents the climate for Desert Grassland Ecological Zone. MAAT is 17.7 C (63.9 F), and results in 931 millimeters (36.64 inches) of pET. MAP is 348 millimeters (13.72 inches) leaving an AWD of 584 millimeters (22.98 inches). Soil temperature regime in the Desert Grassland is thermic and soil moisture regime is ustic aridic.

In the Mixed Prairie ecological zone, Alpine, at 1,356 meters (4,450 feet) elevation, has thermic soil temperature and aridic ustic soil moisture regime. MAAT is 16.4 C (61.5 F) and results in 849 millimeters (33.41 inches) of pET. MAP at 432 millimeters (17.00 inches) is about equal to AWD 416 millimeters (16.36 inches).

From November through April, alternating northwesterly, northeasterly, and southwesterly winds blow, often strongly, bringing in modified air masses: maritime polar, continental polar, and continental tropical, respectively. (Figures 2 and 3). Polar maritime air masses from the North Pacific lose moisture as they pass over the Sierra Nevada and Rocky Mountains. The one common attribute of these air masses is that they are dry. The dew point temperature during the cool season is normally less than -6.5 C (20 F). The months from November through March each receive less than 11 millimeters (0.45 inch) precipitation. Average annual snowfall is less than 5 centimeters (2.0 inches). March is typically the driest month of the year.

During the period of May to June, winds switch to a southeasterly direction (Figures 2 and 3) and maritime tropical air masses bearing moisture from the Gulf of Mexico begin to penetrate to West Texas. The summer monsoon usually starts in early July when dew points increase to 10 C (50 F). The months of July through September receive about half of the annual precipitation total. Afternoon convectional thunderstorm cells of limited extent drop brief bursts of intense rainfall (Figure 4). Most storm totals deliver less than 12.5 millimeters (0.5 inch) of precipitation. On average, only 2 or 3 days per year receive more than 25 millimeters (1.0 inch) of rainfall. Precipitation during August and September is enhanced by tropical cyclone remnants from the Gulf of Mexico and Pacific Ocean.

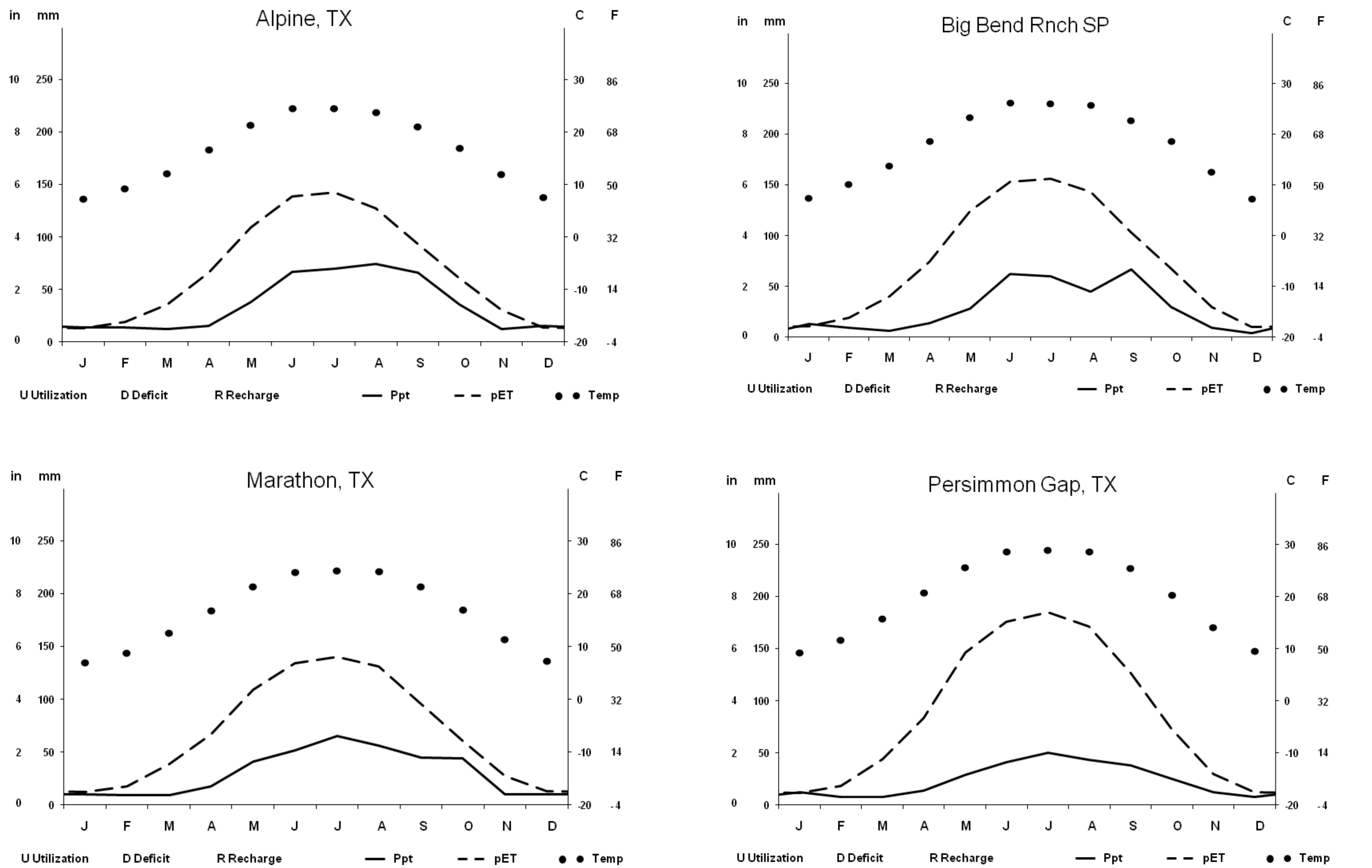


Figure 1. Soil climate diagrams for Alpine, Big Bend Ranch State Park, Marathon, and Persimmon Gap.

Table 1. Climate data for cooperative weather observations near Green Valley, Far West Texas.

	ELEV (m)	ELEV (ft)	MAAT (C)	MAAT (F)	MAX > 100F (days)	MAX > 90F (days)	MAX > 50F (days)	MIN < 32F (days)	FFP (days)
Alpine	1356	4450	16.4	61.5	1.6	54.4	351.3	66.0	211
Big Bend Ranch State Park	1265	4150	17.7	63.9	5.2	88.1	354.7	63.4	
Marathon	1216	3989	16.3	61.4	3.8	74.4	354.2	84.7	
Persimmon Gap	873	2865	19.9	67.8	31.2	140.7	354.3	39.3	256

ELEV = Elevation; MAAT = Mean annual air temperature; FFP = Frost-free period

	pET (mm)	pET (in)	MAP (mm)	MAP (in)	AWD (mm)	AWD (in)	EPIPEDON MOIST (days)
Alpine	849	33.41	432	17.00	416	16.36	106
Big Bend Ranch State Park	931	36.64	348	13.72	584	22.98	74
Marathon	847	33.34	370	14.57	478	18.81	95
Persimmon Gap	1077	42.40	289	11.39	789	31.06	62

pET = Potential evapo-transpiration; MAP = Mean annual precipitation; AWD = Annual water deficit

	0.01 in rain (days)	0.1 in rain (days)	0.5 in rain (days)	1.0 in rain (days)	snow (mm)	snow (in)
Alpine	66.0	35.5	10.4	3.1	33	1.3
Big Bend Ranch State Park	38.5	25.0	8.3	3.0	10	0.4
Marathon	42.2	27.2	10.0	4.0	13	0.5
Persimmon Gap	46.9	23.0	6.7	2.1	13	0.5

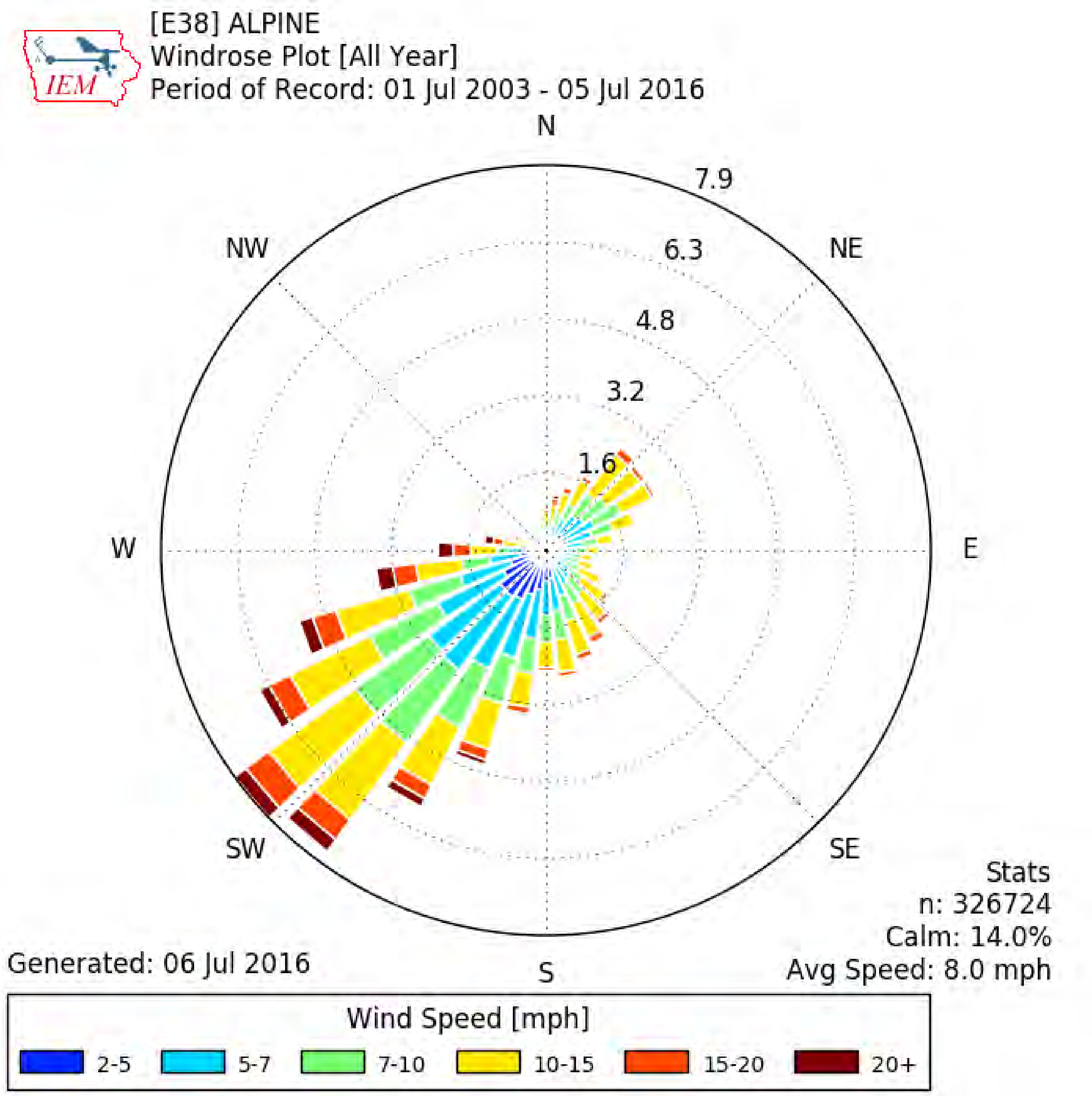


Figure 2. Annual wind rose for Alpine-Casparis airport prepared by the Iowa Environmental Mesonet.

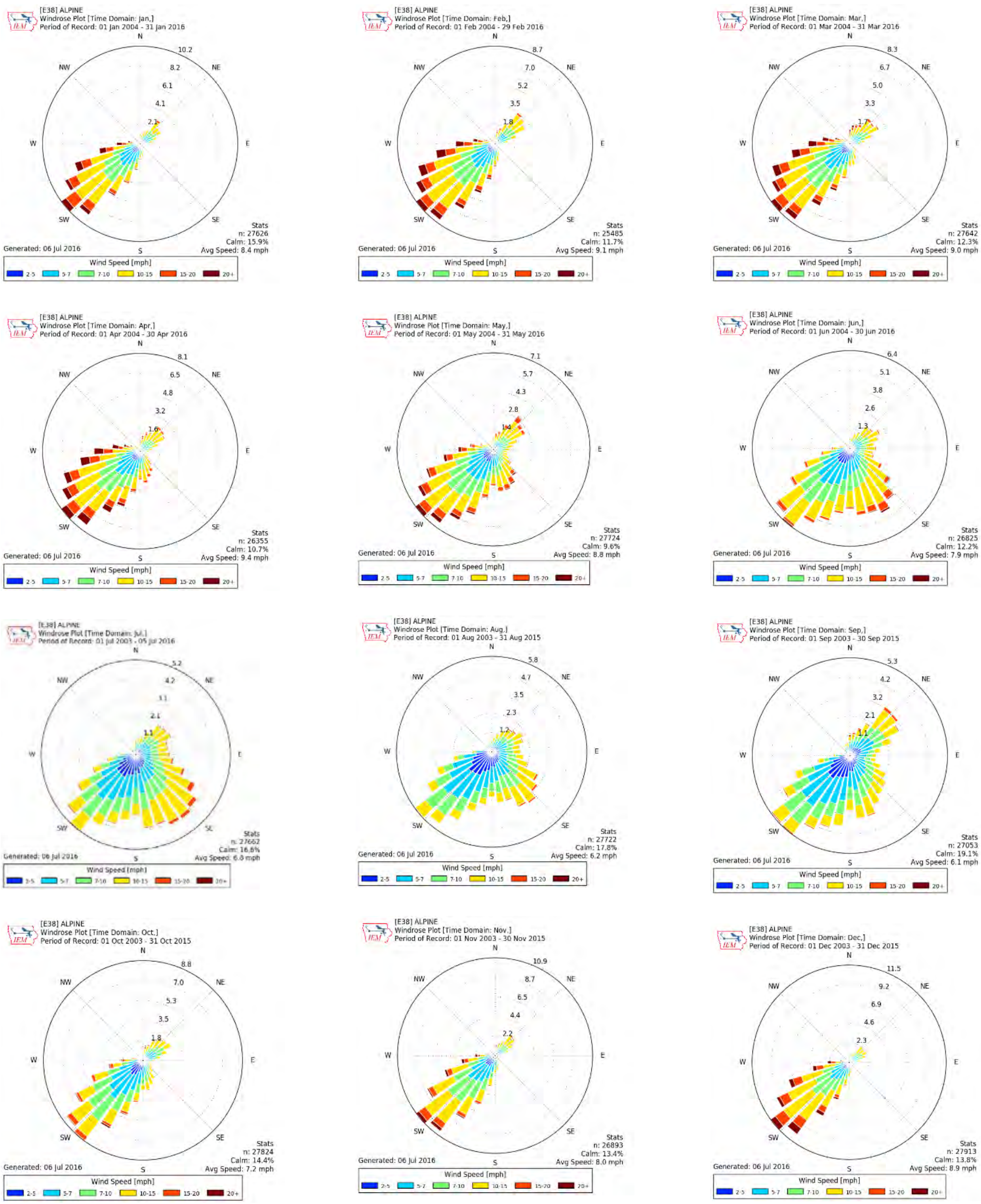


Figure 3. Monthly wind roses for Alpine-Casparis airport prepared by the Iowa Environmental Mesonet.

Figure 4. Rainfall of this intensity occurs about once every 3 or 4 years.

Summer temperatures in the Hot Desert Shrub Ecological Zone are hot. At Persimmon Gap, about 30 days per year reach a maximum temperature of 38 C (100 F) or greater. Summers at Alpine are much cooler with less than 2 days per year hotter than 38 C (100 F). The hottest months of the year in Trans-Pecos Texas are May and June. Higher humidity and the accompanying cloud cover during July and August result in slightly cooler temperatures. The average freeze-free period is from 215 to 225 days long, extending from April through November. Freezing temperatures occur during about half of the nights between first freeze and last freeze.

Evapo-transpiration exceeds precipitation during 11 to 12 months of the year (Figure 1). Only during December and January does precipitation meet or exceed potential water loss. Annual precipitation deficit ranges from nearly 800 millimeters (31 inches) at Persimmon Gap to nearly 415 millimeters (16.36 inches) at Alpine.

Most of Green Valley has an ustic aridic soil moisture regime, with soil moisture gradually decreasing to typic aridic at elevations below 1,070 meters (3,500 feet). A summary of 6 years of soil temperature data confirms that soil temperature regime at Alpine, Marathon, Persimmon Gap, and Big Bend Ranch State Park is thermic. Mean annual soil temperature at elevations below 1,070 meters (3,500 feet) was greater than 22 C (72 F) and soils have a hyperthermic soil temperature regime.

A Summary of the
Geology of the Texas Big Bend

"The geologic history and tectonics of Trans-Pecos Texas are highly complex. Within the area are sedimentary basins and structural arches, bolsons, intrusive igneous bodies, volcanic piles, horsts, grabens, rifts, diapiric emplacements, and plutons. To these are added compressional faults, tensional faults, wrench faults with alternating direction of horizontal displacement, faults with as much as to 16,000 feet of vertical displacement, simple folding, complex folding, two overthrust belts, basin and range tectonics, hot water springs, and mining districts. The area has been tectonically active throughout its entire geologic history and is seismically active today. By contrast, the hydrocarbon rich Permian basin has remained essentially undisturbed for the last 230 million years or since the end of Permian time. Viewed in terms of global tectonics, Trans-Pecos Texas has been influenced by compressional and shear stresses generated by plate collisions in Precambrian and Permo-Pennsylvanian time and compressional stresses due to plate movements in Devonian-Mississippian and Laramide times. Superimposed on this is an overprint of Tertiary Basin and Range tensional tectonics." (DeJong and Addy, 1992a)

"In studying the geology of the Chisos country, one must constantly bear in mind that the terranes which we now find exposed at the surface have been laid bare from under a covering of overlying rocks measuring from two to ten thousand feet in depth. This great thickness of vanished strata has been removed during a long lapse of time, which commenced with the closing stage of the Cretaceous age. We should also remember that during the time this work of disintegration and removal was going on, and even before it began, the whole ground has been subjected to forces which have thrown the strata into folds and flexures and broken them by great faults into blocks that are extensively tilted." (Udden, 1907)

Introduction

Rocks exposed within Brewster, Jeff Davis, and Presidio Counties range in geologic age from Late Cambrian to Holocene, from about 510 million years in age to less than 10,000 years. Big Bend Counties occur mainly within three 1:250,000 scale sheets of the Geologic Atlas of Texas: Marfa, Fort Stockton, and Emory Peak-Presidio. According to the Geologic Database of Texas (Stoeser et al., 2005), some 149 named geologic map units or formations are mapped within the Big Bend Counties. The Geologic Map of Texas compiled at 1:500,000 scale (Barnes, 1992; Stoeser et al., 2005) combined these into 96 different geologic map units.

The rocks in the Big Bend region originated from igneous and sedimentary processes. Important rock types include limestone, sandstone, mudstone, rhyolite, basalt, tuff, and conglomerate as well as gravelly sediments and non-gravelly sediments. This diverse age, origin, and lithology of rocks is further complicated by many faults that place different rocks side-by-side on the land surface.

Stratigraphy

For this discussion, the geologic formations have been arranged into six groups defined by geologic time and general lithology: pre-Permian rocks, Permian limestone, Lower Cretaceous limestone, Upper Cretaceous rocks, Tertiary volcanic rocks, and Quaternary age surficial deposits (Figure 5).

Pre-Permian Rocks

Pre-Permian rocks outcrop on about 30,000 hectares (75,000 acres) in the Marathon Basin and within the Solitario. Exposed rocks range in age from Cambrian to Pennsylvanian (McBride, 1988). They have a total thickness from 16,000 to 21,000 feet. The initial stages of deposition within a marine environment, from Cambrian to Mississippian, occurred slowly. Only about 945 meters (3,100 feet) of sediments were deposited during a time span of 170 million years (McBride, 1988). Cambrian-age Dagger Flat sandstone, Ordovician-age formations include the Marathon limestone, Alsate shale, Fort Pena Formation, and Woods Hollow shale. The Ordovician-age Maravillas Formation contains black chert whereas the Caballos Formation (Mississippian and Devonian age) has white novaculite (Figure 6). The geologic age and composition of the Caballos Novaculite is very similar in to the Arkansas Novaculite, which is famous as superior whetstone for sharpening knife edges.

Most of the Paleozoic interval (3,950 meters [13,000 feet]) was deposited during the Pennsylvanian and Permian periods (McBride, 1988). Pennsylvanian-age rocks include the Tesnus shale, Dimple limestone, Haymond Formation, and Gaptank Formation. The Tesnus shale is 90 to 2,100 meters (300 to 7,000 feet) thick. The Haymond and Gaptank Formations consist of limestone, sandstone, and shale. Rocks of Pennsylvanian-age and older were extensively folded and faulted during the Ouachita Orogeny (Figure 7). Many high-relief folds occur within the Marathon area.

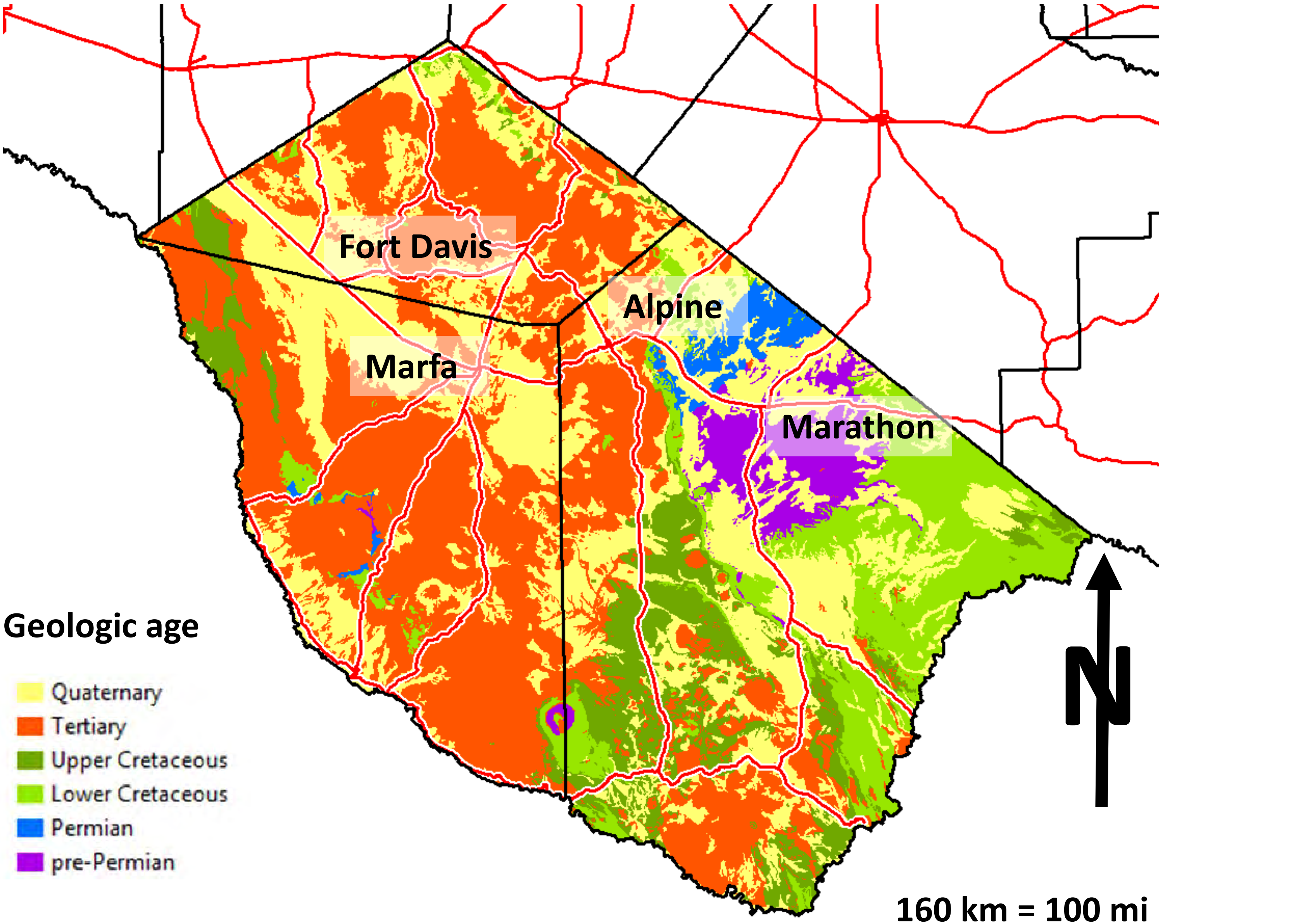


Figure 5. Generalized geologic map of the Texas Big Bend Region.

Figure 6. Flatirons of Mississippian-Devonian-age Caballos novaculite on hill west of US Highway 285, about 7 miles south of Marathon in central Brewster County.

Figure 7. Upturned beds of Pennsylvanian-age Dimple limestone along US Highway 90 at Lemons Gap, east of Marathon in eastern Brewster County.

Permian

During the Permian period, dolomite and limestone were deposited in a marine environment. About 40,000 hectares (100,000 acres) of exposed Permian carbonate rocks in the Glass Mountains compose the Leonard, Word, and Capitan Formations (King, 1930). The Permian-age Ross Mine, Mina Grande, Pinto Canyon, Alta, and Cibolo Formations partially encircle the Chinati Mountains in Presidio County. These formations are also composed mainly of limestone and crop out over about 4,450 hectares (11,000 acres).

Following the Permian period, oceans withdrew from the Big Bend Region and a time of non-deposition and extensive geologic erosion ensued. Rocks of Triassic and Jurassic periods are mostly absent from the Big Bend counties.

Cretaceous

The Cretaceous rocks of Brewster County and eastern Jeff Davis and Presidio Counties were laid down mainly in a shallow marine environment (Diablo Platform). The Cretaceous rocks in the western Big Bend area were deposited in the Chihuahua Trough, a deep marine setting.

Lower Cretaceous rocks in the eastern Big Bend area are almost entirely limestone (Graves, 1954; Henry and Muehlberger, 1996; Figure 8). The Glen Rose, Santa Elena, Sue Peaks, Del Carmen, Fort Terrett, Fort Lancaster (=Segovia of the central Edwards Plateau), and Buda Formations compose a sequence of carbonate rock about 760 meters (2,500 feet) thick covering 365,000 hectares (900,000 acres). In western Presidio County, about 44,500 hectares (110,000 acres) of Lower Cretaceous rocks crop out, including the Yucca, Bluff Mesa, Cox, Shafter, Presidio, Benavides, and Finlay Formations. All formations except Cox sandstone are dominantly limestone.

Upper Cretaceous rocks are composed of mudstone, flaggy limestone, and sandstone. About 230,000 hectares (575,000 acres) of Upper Cretaceous rocks are exposed in the eastern Big Bend region, and about 17,500 hectares (43,000 acres) in western Presidio County. Eastern Big Bend formations are the Boquillas flaggy limestone, mudstones of the Del Rio, Pen, and Javelina Formations, and Aguja sandstone. The El Picacho Formation, San Carlos sandstone, and Ojinaga Formation outcrop in western Presidio County.

At the end of the Cretaceous period, shallow seas began to withdraw from West Texas. The Laramide orogeny significantly influenced the rocks and landscapes of Big Bend. Compressional forces during the Late Cretaceous and early Tertiary created uplifts, basins, faults, and folds in a zone extending from Mexico to Canada. Thrust faults adjacent to the Santiago Mountains are among the features formed during this period. Thrust faults during this period formed Sierra Grande immediately west of the Rio Grande in Mexico.

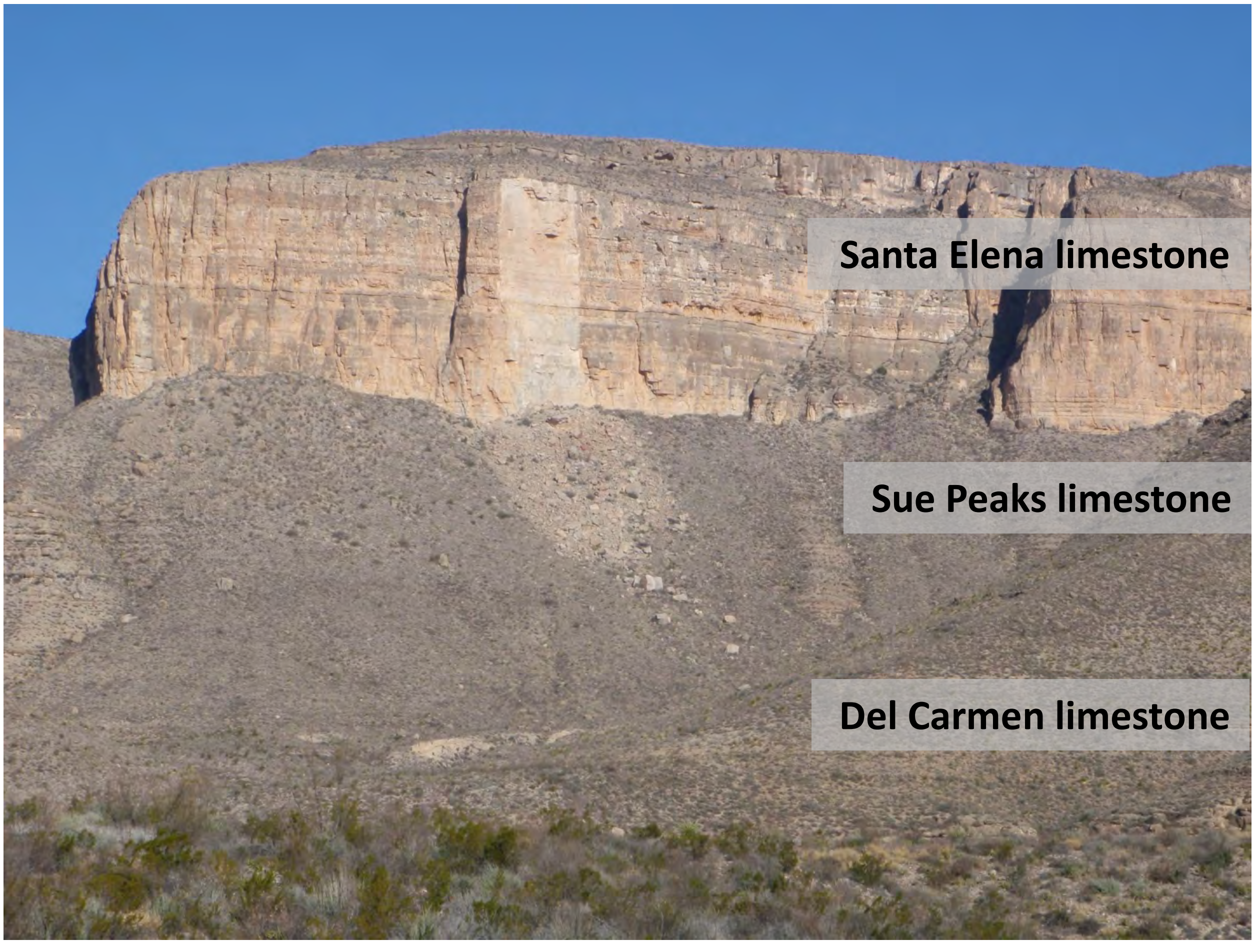


Figure 8. Lower Cretaceous limestone formations exposed in valley of Maravillas Creek, Black Gap Wildlife Management Area, in southern Brewster County.

Mid-Tertiary Volcanism

About 1,075,000 hectares (2,650,000 acres) of Tertiary-age rocks, almost entirely igneous, occur in the Big Bend counties. The area lies within the Trans-Pecos Volcanic province, a large area of intrusive, volcanic, and volcaniclastic rocks deposited during Eocene and Oligocene epochs (Parker, 1988; Price et al., 1986; Figures 9 and 10).

Volcanic vents that shed lava or volcanic sediments to the Big Bend area include Eagle Mountains and Quitman Mountains calderas in Hudspeth County; Wylie Mountains and Van Horn calderas in Culberson County; Chinati, Infernieto, and Solitario Dome calderas as well as several vents on the Bofecillos Plateau in Presidio County; Buckhorn, Paradise Mountain, and Muerto calderas in Jeff Davis County; and Paisano Pass, Pine Canyon and Sierra Quemada calderas in Brewster County. Just south of the Rio Grande in Chihuahua, Mexico, are the San Carlos and Santana calderas. The Trans-Pecos volcanic province is part of a larger area of volcanic activity that formed the Sierra Madre Occidental in Mexico and Mogollon-Datil Mountains in western New Mexico (Henry, 1986; Figure 9).

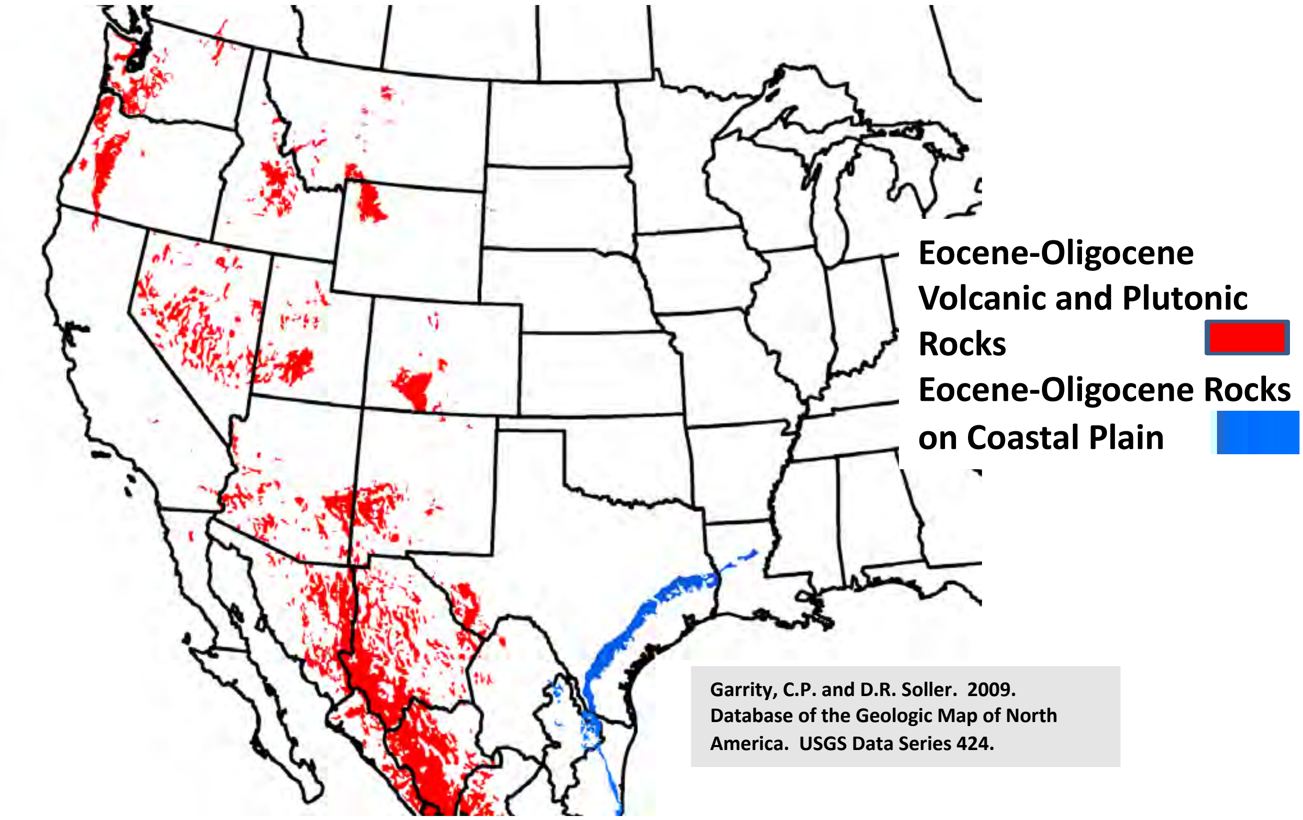


Figure 9. Map of Eocene-Oligocene-age volcanic -plutonic rocks and Gulf Coast deposits.

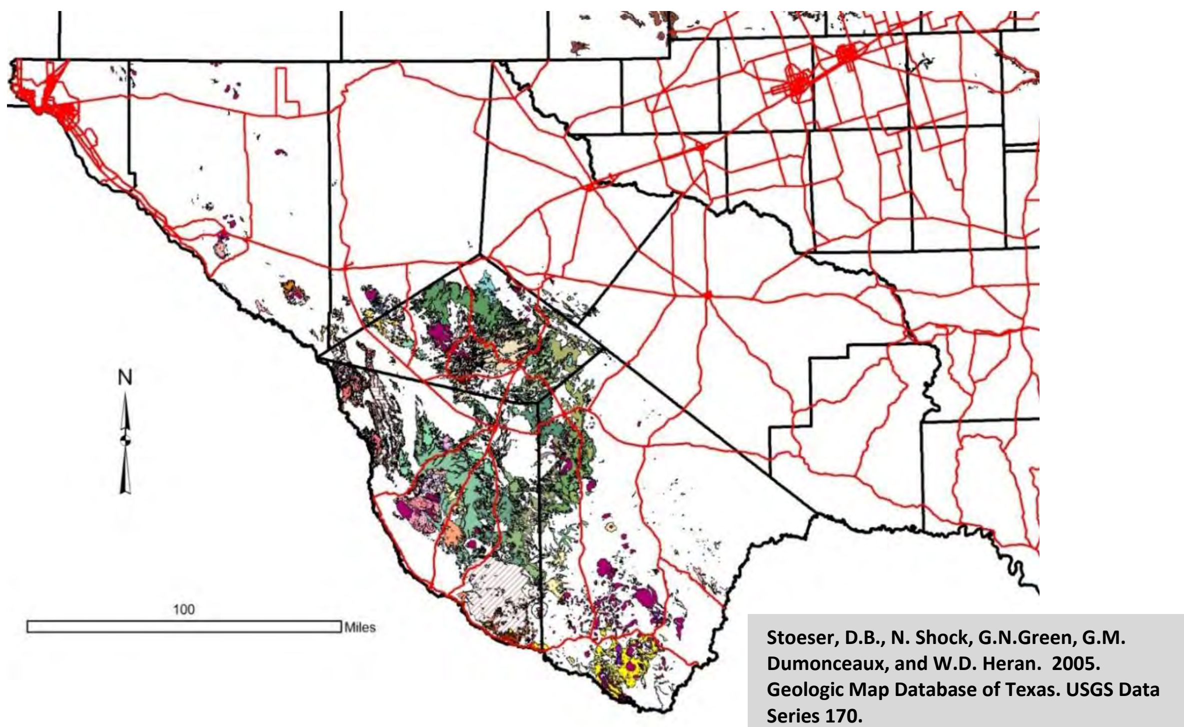


Figure 10. Map of Tertiary-age rocks, mainly igneous, in Far West Texas.

The Tertiary volcanic pile is about 900 to 1,200 meters (3,000 to 4,000 feet) thick, and consists of rhyolite, trachyte, basalt, ignimbrite, and volcanic sediments. Basalt flows are usually thin (some flows are only 1 to 2 meters (3 to 6 feet) thick), whereas the rhyolitic units can be as much as several hundred feet thick. Volcaniclastic sediments include reworked ash-flow tuff, mudstone, sandstone, and conglomerate.

Extrusive igneous rocks cover much of northern and western Brewster County. Dark-colored basalt bedrock rich in basic cations occurs within the Sheep Canyon, Cottonwood Spring, and Petan Formations (McAnulty, 1955). The Crossen and Decie Formations are composed of trachyte or rhyolite, light colored, silicic igneous rocks.

Resulting from eruptions to the north and west, the Eocene-Oligocene-age Duff, Pruett, and Devils Graveyard Formations contain a number of volcaniclastic rock types: tuffaceous mudstone, tuffaceous sandstone, and conglomerate (Goldich and Elms, 1949).

A similar sequence of volcanic and volcaniclastic rocks occurs in western Presidio County. The Vieja group consists of the Jeff conglomerate, Gill breccia, Colmena Formation, Buckshot ignimbrite, Chambers Formation, and Bracks rhyolite, and Capote Mountain Formation (DeFord and Bridges, 1958; Walton, 1977). The Colmena, Chambers, and Capote Mountains Formations consist mainly of tuffaceous sedimentary rocks. The Buckshot and Bracks Formations are rhyolitic lava flows.

The Mitchell Mesa ignimbrite resulted from the cataclysmic eruption of the Chinati supervolcano in present-day Presidio County about 31 million years ago (Figure 11). This formation is characterized by grey to pink rhyolite; angular clear quartz and blue feldspar crystals that commonly protrude above the weathered surface. Covering about 40,000 hectares (100,000 acres), the ignimbrite is 40 to 150 feet thick and effectively caps the highlands west of Green Valley. In places, the erosional scarp held up by the Mitchell Mesa is more than 300 meters (1,000 feet) high.

Tuffaceous sediments of the Tascotal, San Carlos, Fresno, and Santana Formations occur mainly in Presidio County. The Tascotal Formation was deposited during the initial stages of geological dissection of Chinati Volcano following its catastrophic eruption. About 45000 hectares (115,000 acres) of material with zeolitic mineralogy and very high cation exchange capacity remain. The Oligocene-age Perdiz conglomerate resulted from the erosion of Chinati Volcano. The Perdiz consists of 107,000 hectares (265,000 acres) of alluvial fan deposits, cemented by silica during deposition. The late Oligocene-age Rawls Formation consists mainly of basalt and trachyte. These volcanic rocks, covering 105,000 hectares (240,000 acres) in Big Bend Ranch in southern Presidio County, issued from Bofecillos volcano and other local vents (Henry, 1998).

In the Big Bend counties, relatively small individual areas of intrusive igneous rocks, mainly syenite and with some granite, occupy almost 105,000 hectares (260,000 acres). Intrusive rocks are resistant to weathering and erosion, and frequently cap summits.

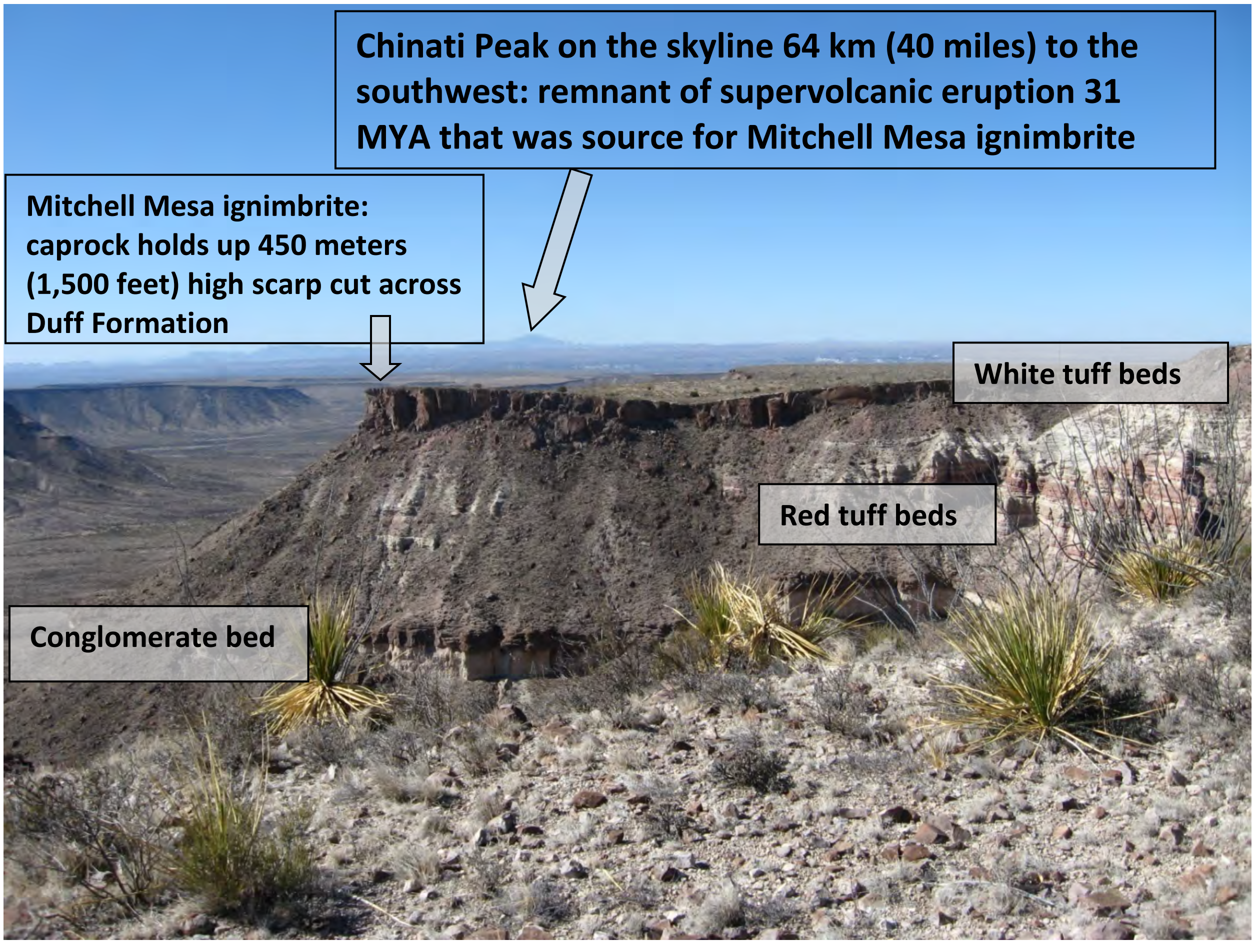


Figure 11. View of Chinati Peak from the top of Mitchell Mesa. The Mitchell Mesa ignimbrite caps beds of white tuff, red tuff, and conglomerate within the Duff Formation.

Structure

Green Valley lies just west of a major thrust fault along the Santiago Mountains. Several faults trace generally northwest-southeast across Green Valley. Faults complicate the pattern of soils by placing different rocks unpredictably side-by-side on the land surface. The hanging wall or down-dropped side of most faults is on the south. Named major faults from north to south are the Walnut Draw Fault, Chalk Draw Fault, Hale Cabin Fault, White Trail Fault, Cheosa Waterhole Fault, Fizzle Flat Fault, and Tascotal Mesa Fault.

Between the Walnut Draw and Chalk Draw faults is a graben structure. On the south side of this graben the Chalk Draw fault is buried by mid-Pleistocene Montgomery Lake alloformation that underlies the Green Valley Ranch geomorphic surface. By the principle of superposition, the last significant fault movement occurred before formation of the pediment surface.

Extensional faulting during Miocene and Pliocene epochs created the Basin and Range landscapes that characterize Far West Texas. Graben tectonic blocks dropped relative to upthrown horsts. The Miocene-age Tarantula gravel in western Presidio and Jeff Davis Counties is a piedmont slope gravel deposited after approximately 2,000 feet of vertical offset occurred along the Rim Rock fault (DeFord and Bridges, 1958). Closed basins similar to Salt Basin in Culberson County existed in southern Presidio and Brewster

Counties. Saline and gypsum-bearing clayey bolson-fill deposits were deposited within the Presidio and Redford bolsons by an ancient Rio Conchos (Groat, 1972). Northwest of Green Valley is Mitchell Flat, a semi-bolson that is drained and dissected by Alamito Creek, a tributary of the Rio Grande. Ryan Flat west of Marfa appears to be a slightly dissected basin floor of the Wild Horse semi-bolson.

Erosion

The Pliocene and Pleistocene epochs are characterized by extensive geological erosion. In 1907, University of Texas geologist John Udden wrote "In studying the geology of the Chisos country, one must constantly bear in mind that the terranes which we now find exposed at the surface have been laid bare from under a covering of overlying rocks measuring from two to ten thousand feet in depth." (Udden, 1907)

About 2 million years ago external drainage was established when the Rio Grande breached bedrock divides between bolsons (Gustavson, 1991). Following the establishment of external drainage, erosion has been the dominant geomorphic process in the Big Bend counties. In the Chisos country of southern Brewster County, erosion has removed from 600 to 3,000 meters (2,000 to 10,000 feet) of material since the end of the Cretaceous (Udden ,1907). The eroded material was transported by the Rio Grande and deposited along the margins of the Gulf of Mexico. The Jackson and Catahoula groups of the Gulf Coastal Plain trace their origin to the Trans-Pecos volcanic field.

Surficial deposits

Quaternary-age surficial deposits (Albritton and Bryan, 1939) cover much of the Big Bend area. These include landslide deposits, colluvium, pediment-capping gravel deposits, alluvial-fan deposits, and stream and river alluvium. The sediments contain records of dramatic climate change during the Pleistocene and Holocene epochs. Furthermore, they are important sources of soil parent materials. Typically soils that formed in transported parent materials are deeper and more productive than those forming in residuum.

On the Emory Peak-Presidio Geologic Atlas Sheet (Brown et al., 1979) recognized three ages of Quaternary deposits in Green Valley. Young Quaternary deposits include Qal, alluvium and low terrace deposits along streams (Duff Creek, Calamity Creek), and Qf, colluvium and fan deposits. Old Quaternary deposits (Qao) consist of alluvium, colluvium, and caliche on surfaces dissected by modern drainage.

Landslide deposits are mapped on the side of Elephant Mountain. Colluvium occurs on long steep slopes, especially over recessive tuffaceous beds. Remnants of pediment and alluvial fan deposits of mid to late Pleistocene age occur throughout the Big Bend counties. The flood plain of the Rio Grande is non-gravelly alluvium. Alluvial flat deposits are also non-gravelly, whereas flood plain deposits of high velocity tributaries are gravelly. Except for coppice mounds beneath shrubs in some areas, eolian parent materials are not significant in the Big Bend Counties. Further information can be found on eolian deposits mapped by Dietrich near Presidio that are actually saline alluvium. (Dietrich, 1966)

Stupendous Geologic Erosion from Green Valley

Igneous rocks formed by cooling and solidification from molten magma, and have not been changed appreciably by weathering since its formation. Igneous rocks are classified according to chemical composition and crystal size. Extrusive or volcanic rocks are extruded or erupted to the surface and cool rapidly, quenching the melt to glass. Intrusive igneous rocks are derived from molten matter (magmas) that invaded pre-existing rocks and cooled below the surface of the earth. Slow cooling beneath a blanket of roof rock results in crystallization of the melt. Intrusive rocks are phaneritic, i.e., macroscopic crystals compose the rock.

A sill results from magma that intrudes between strata of bedded rocks and then cools. Sills are exposed at the summits of Elephant Mountain, Nine Point Mesa, and Buck Hill (Goldich and Elms, 1949; McAnulty, 1955). Whereas the former roof rock has been removed, sills that cap those landforms are resistant to further erosion. Incision of the stream channels has left the caprock sills high above the drainage network. The timing of this erosional stripping is constrained since intrusive emplacement during the Eocene or Oligocene age.

Figure 12 displays for intrusive-capped crests in Brewster and Presidio Counties: 1) elevation of the summit; 2) elevation of the nearest stream channel; and 3) height of summit above that stream. The figure is oriented as if looking east from Green Valley, with north positioned to the left. A stream is defined as a channel with 10 million m^2 (approximately 2,500 acres) of contributing area as calculated with TauDEM software (Tarboton, 1997, Tesfa et al., 2009).

Average elevation of intrusive capped summits is 1,612 meters (5,289 feet), ranging from nearly 2,000 meters (6,562 feet) at Cienega Mountain and Santiago Peak to the minimum of 1,190 meters (3,904 feet) at Straddlebug Mountain. The highest peaks are in the northern part of the transect with elevation decreasing southward toward the Rio Grande River.

The elevation of the drainage network nearest the peak averages approximately 1,140 meters (3,740 feet). The pattern of stream network elevation parallels elevation of peaks. The highest stream (1,514 meters [4,967 feet]) near McIntyre Peak is at the north extremity; the lowest stream elevation near Hen Egg Mountain is 870 meters (2,854 feet) at the southern end of the transect.

Height (of peak) above stream is a measure of erosion that has transpired since the emplacement of the intrusive sills. The average height above stream value for the transect is nearly 475 meters (1,558 feet). The inferred erosion has taken place since the Oligocene age which ended 23 Ma. The area surrounding eight peaks has experienced more than 500 meters (1,640 feet) of erosional stripping. The summit of Santiago Peak lies 877 meters (2,877 feet) above the channel of Chalk Draw whereas the height of Straddlebug Mountain above Terlingua Creek is 97 meters (318 feet).

A second monument of stupendous erosion from Green Valley is the scarp held up by the Mitchell Mesa ignimbrite. The Mitchell Mesa ignimbrite caps the highlands west of Green Valley and overlooks the terrain exposed by erosion. The ignimbrite was erupted 31 Ma from the Chinati supervolcano in southwestern Presidio County, approximately 65 kilometers (40 miles) west of the O2 Ranch headquarters. On the list of the 47 largest known explosive eruptions (Mason et al., 2004), Chinati volcano is number 21. A turbulent mixture of gas and pyroclastic material, mostly particles of ash size, explosively ejected from the caldera and then moved across the land surface. The superheated volcaniclastic material suspended in the ash cloud precipitated and welded on contact. The volume of ejected material occupied approximately 1,000 km^3 (240 mi^3); its estimated weight was 3.5×10^{15} kg (3,858 billion tons). Because of its wide extent, the Mitchell Mesa is a key unit for correlating geological units in the southern Big Bend region (Maxwell and Dietrich, 1970).

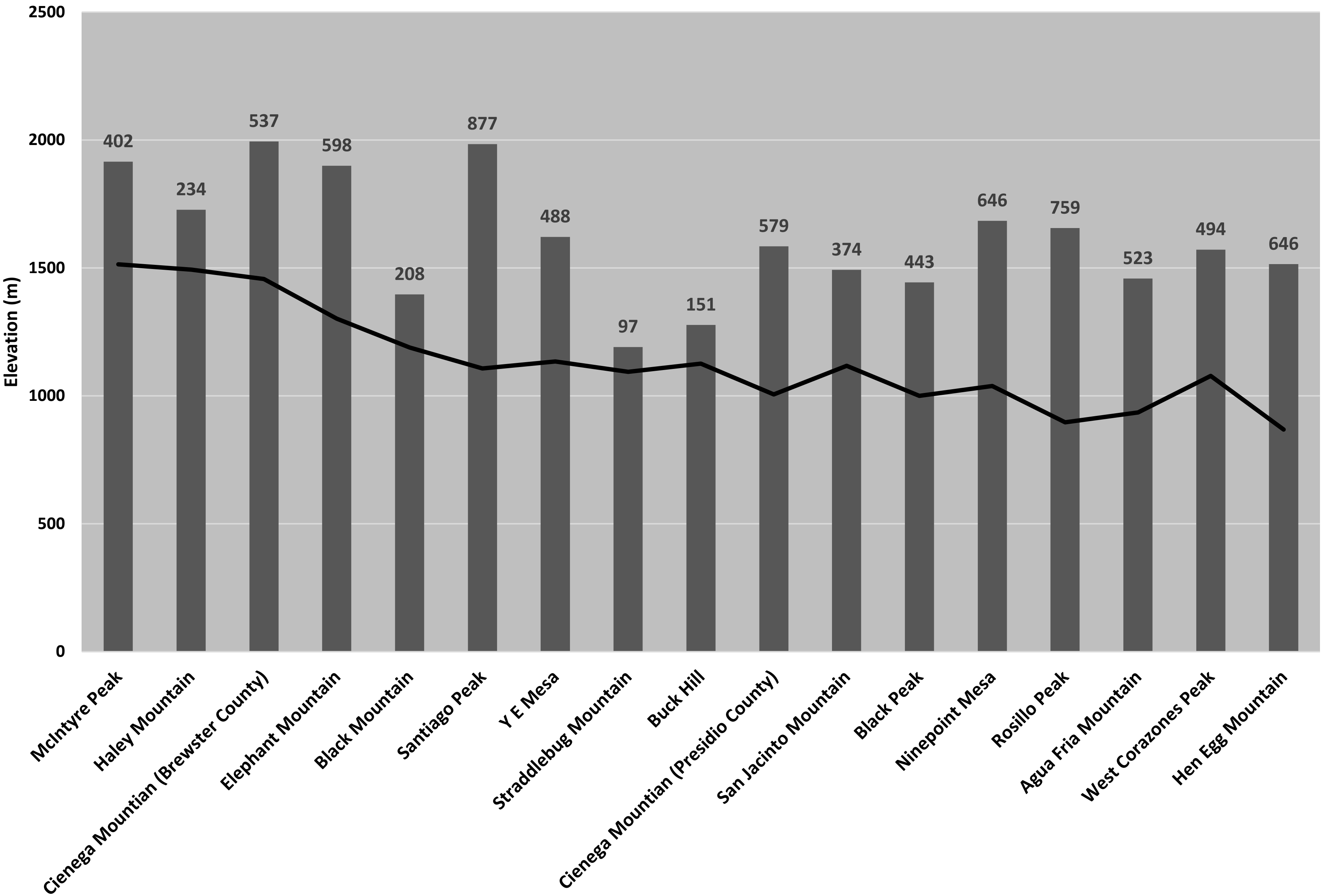


Figure 12. Elevation of summit (bar) and nearest stream (line), and depth of erosion (number above bar) for intrusive-capped peaks in the southern Big Bend region.

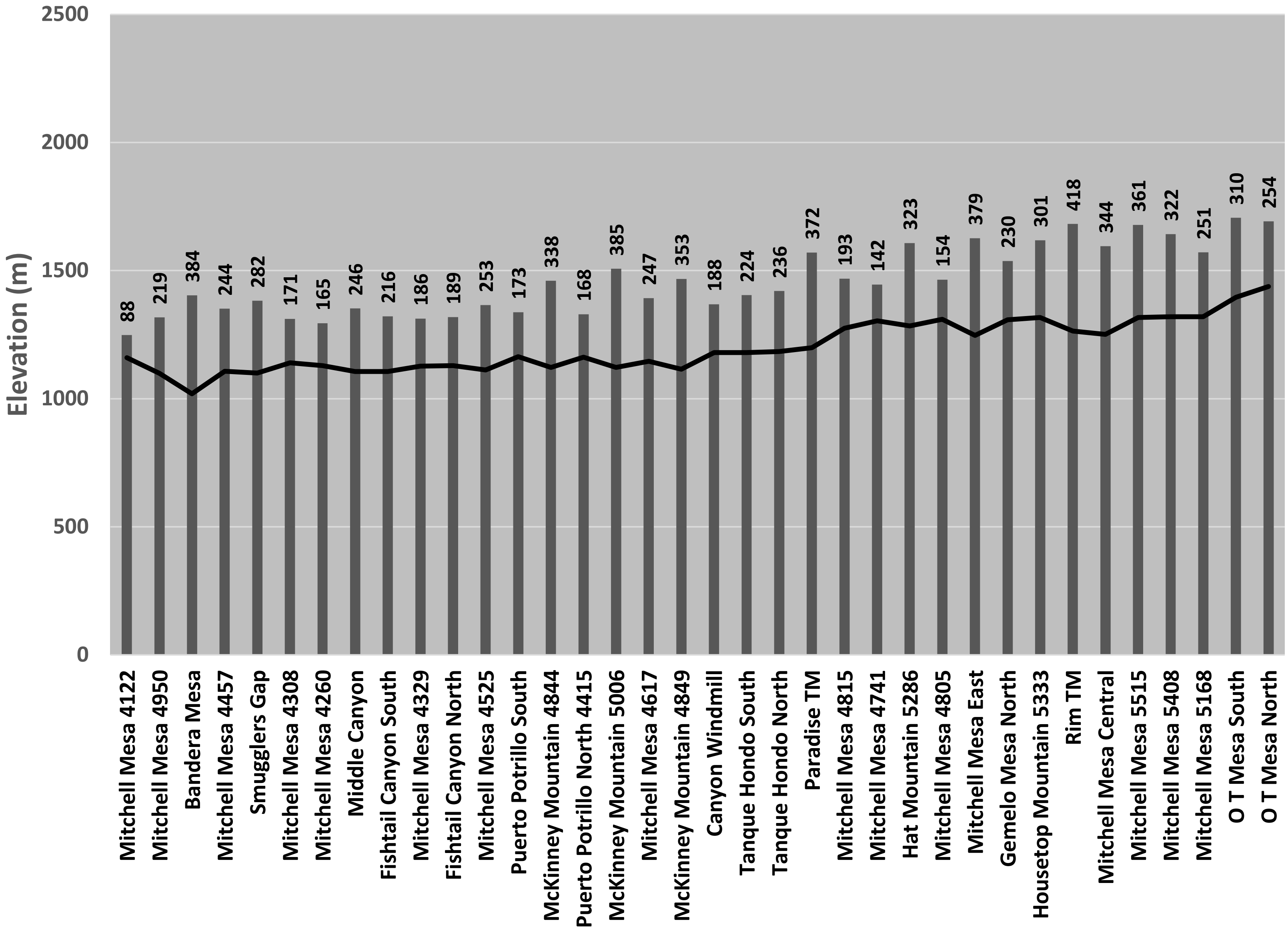


Figure 13. Elevation of summit (bar) and nearest stream (line), and depth of erosion (number [m] above bar) for landforms capped by Mitchell Mesa ignimbrite in the southern Big Bend region. North is to the right.

Following 31 Ma of geologic erosion, ignimbrite outcrops remain at these distances from Chinati Peak: 1) on Terry Mesa just 14 kilometers (8.5 miles) southwest of Alpine and 80 kilometers (50 miles) northeast from Chinati volcano; 2) capping foothills of Sierra Vieja 76 kilometers (47 miles) northwest of Chinati and 10 kilometers (6 miles) south of Valentine; and 3) at Big Bend Ranch State Park 64 kilometers (40 miles) southeast of the vent. Areas of Mitchell Mesa mapped within Big Bend National Park are not actually ignimbrite erupted from the Chinati volcano (Brown et al., 1979); these areas were remapped as a rhyolite member of the Burro Mesa Formation (Turner et al., 2011).

Height above stream as a quantitative measure of erosional stripping was calculated for selected summits overlooking Green Valley. Figure 13 looks west from Green Valley toward the Jordan Gap scarp capped by ignimbrite. Elevation of mesa summits and of drainage networks is generally highest in the north, descending toward the south. Highest mesa elevation is 1,706 meters (5,597 feet) and stream elevation is 1,437 meters (4,715 feet) are at O T Mesa located north of Green Valley. The lowest ignimbrite caprock elevation is 1,248 meters (4,094 feet) and the minimum stream elevation is 1,019 meters (3,343 feet), both at the southern end of the transect. Below the Jordan Gap scarp, average elevation of drainage network is 1,200 meters (4,094 feet). Bandera Mesa is 88 meters (289 feet) above Alamo de Cesario Creek. The Rim triangulation station on Mitchell Mesa is 418 meters (1,371 feet) above Davenport Creek.

Ignimbrite fragments have a characteristic brown weathering coat and contain clear quartz and blue sanidine phenocrysts (Figure 14). Fragments derived from ignimbrite bedrock are readily distinguished from rhyolite, trachyte, and basalt fragments. Ignimbrite fragments, mainly gravel but ranging in size to boulders, cover the Green Valley Ranch, Sid Place, and Dogie Creek geomorphic surfaces in Green Valley. Testifying to the transporting energy that accomplished stupendous erosion, a boulder of Mitchell Mesa ignimbrite was observed on a dissected piedmont in Black Gap Wildlife Management Area, 70 kilometers (40 miles) east of the nearest outcrop.

Figure 14. Partially buried by limestone gravel, this stone-size fragment of Mitchell Mesa ignimbrite with tell-tale quartz and sanidine crystals (inset) is on a high terrace remnant in Terrell County, approximately 30 kilometers (18 miles) southeast of Sanderson, 140 kilometers (85 miles) east of the nearest outcrop. (Photo by Amanda Bragg, USDA NRCS.)

Quaternary Geomorphology and Stratigraphy of the Straddlebug Mountain Quadrangle

The Straddlebug Mountain USGS 7.5 minute topographic quadrangle is in west-central Brewster County, approximately 35 miles south of Alpine. It lies within the heart of Green Valley. The O2 Ranch headquarters is within the quad near the western edge. Most of the quadrangle is characterized by gently sloping surfaces, interrupted by short hilly slopes (Figure 15). Elevated topographic features include Straddlebug Mountain and Goat Trap Hill. Most of the quad area has low relief though elevation ranges from approximately 1,260 meters (4,135 feet) on the crest of Goat Trap Hill to 1,075 meters (3,525 feet) along the channel of Terlingua Creek where it exits the quad.

A geomorphic surface is a mappable area of the earth's surface that has a common history. Landforms of a geomorphic surface have similar age and formed by a set of processes during a particular period of landscape development. A geomorphic surface can form through erosional processes, constructional processes, or both. The shape of a geomorphic surface can be planar, concave, convex, or any combination of these identified in (Ruhe, 1956).

This section describes seven alluvial geomorphic surfaces (Table 2, Figure 15) that occur in or near the quadrangle, their interrelationships, as well as relationships to various landform metrics computed from IFSAR data (Figures 16 and 17). In addition, their associated allostratigraphic deposits will be described. An allostratigraphic unit is a mappable body of rock that is defined and identified on the basis of its bounding discontinuities (North American Commission on Stratigraphic Nomenclature 2005). The fundamental unit is the alloformation. Of three erosional geomorphic surfaces in the quad, only one will be discussed.

Table 2. Estimated age, mean elevation, height above stream, and slope gradient of alluvial geomorphic surfaces within the Straddlebug Mountain quadrangle.

Alluvial Geomorphic Surface	**Age**	**Elev meters**	**AVS10M meters**	**Slope (percent)**
Sid Place	early-Pleistocene	1,145	35	1.1
Green Valley Ranch	early mid-Pleistocene	1,115	26	0.7
Plank House	late mid-Pleistocene	1,155	15	0.8
Eleven Section	late-Pleistocene	1,118	6	1.7
O2 Ranch	early Holocene	1,132	11	1.1
Oil Pad	late Holocene	1,115	1	1.7

Elev = Elevation; AVS10m = Height above stream

The source of alluvium that covers much the Straddlebug Mountain quad as well as Green Valley is tuffaceous bedrock of the Duff Formation exposed on the Jordan Gap geomorphic surface. Rock fragments are derived from weathering of Mitchell Mesa ignimbrite, Cottonwood Spring basalt, and Crossen trachyte.

The Loma Largo geomorphic surface does not occur in the Straddlebug Mountain quadrangle. Isolated Loma Largo pediments occur high above local base level at the edge of Green Valley and in its interior. At the mouth of Beef Canyon 10 miles northwest of the O2 Ranch headquarters, a Loma Largo pediment is situated 70 meters (230 feet) above stream level. This area is proximal to the Jordan Gap geomorphic surface, the western edge of Green Valley. Approximately 17 miles south of the headquarters is a Loma Largo talus flatiron, also near the Jordan Gap scarp, 100 meters (328 feet) above base level. In the middle of Green Valley, 9 miles southeast of the headquarters on the crest of Long Hills, is a pediment remnant.

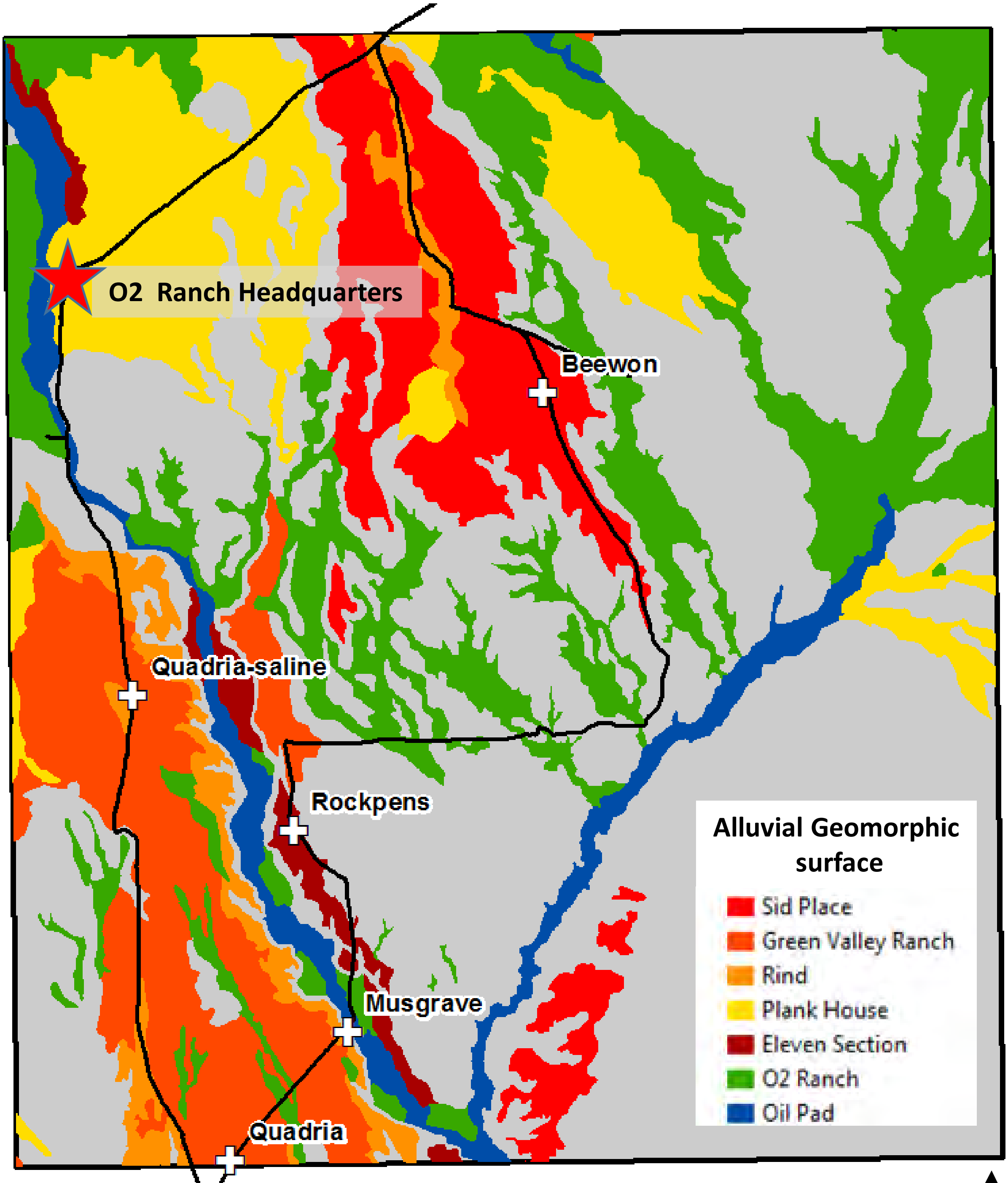
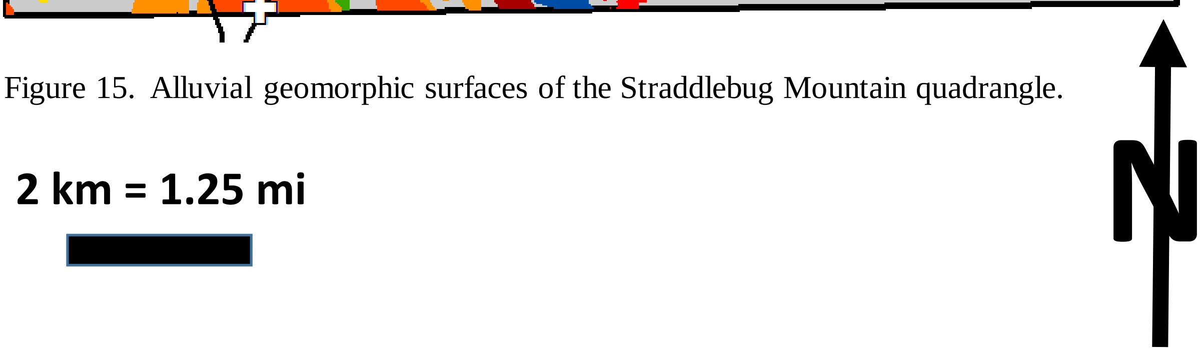


Figure 15. Alluvial geomorphic surfaces of the Straddlebug Mountain quadrangle.



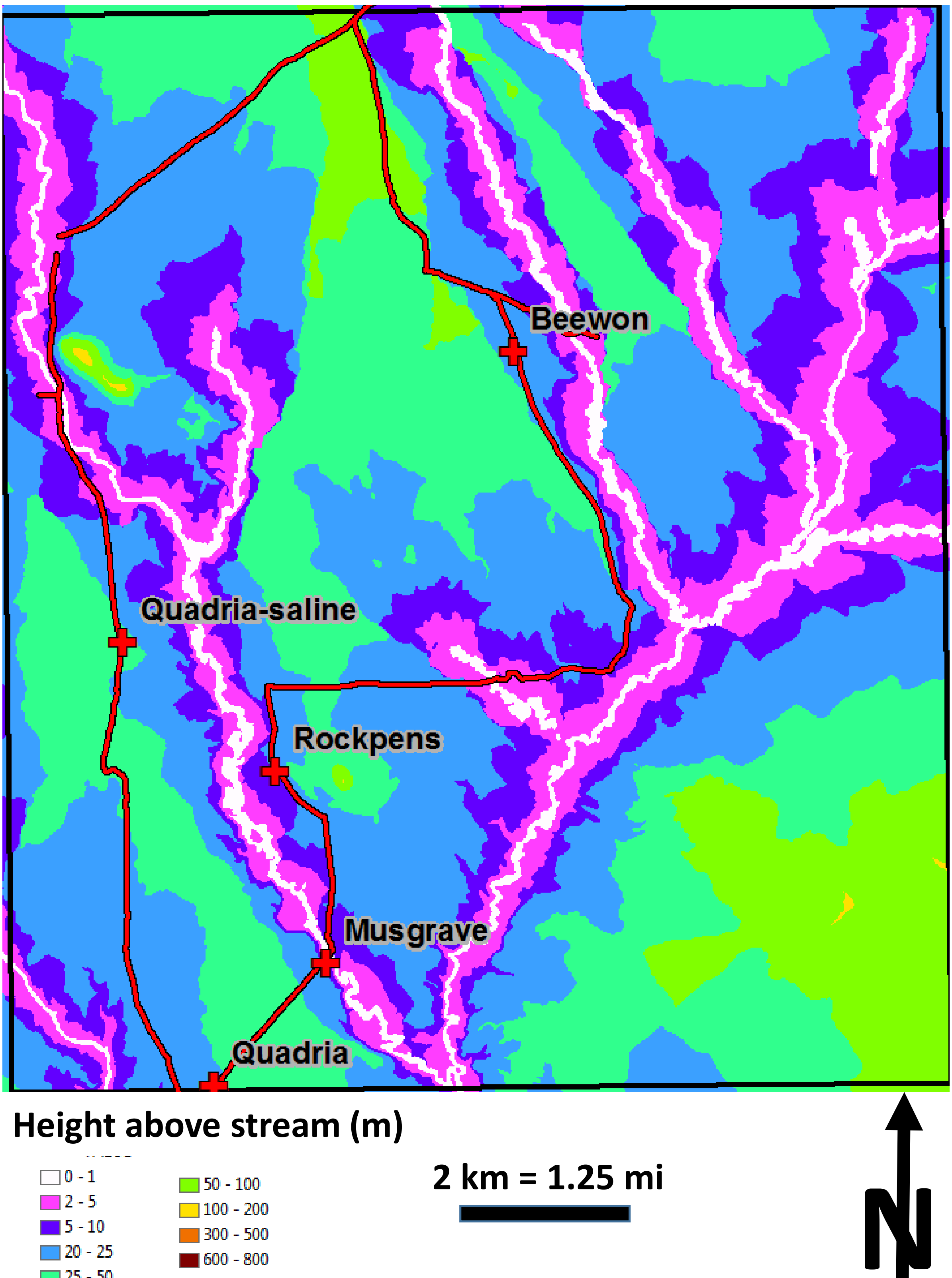


Figure 16. Height above stream within the Straddlebug Mountain quadrangle.

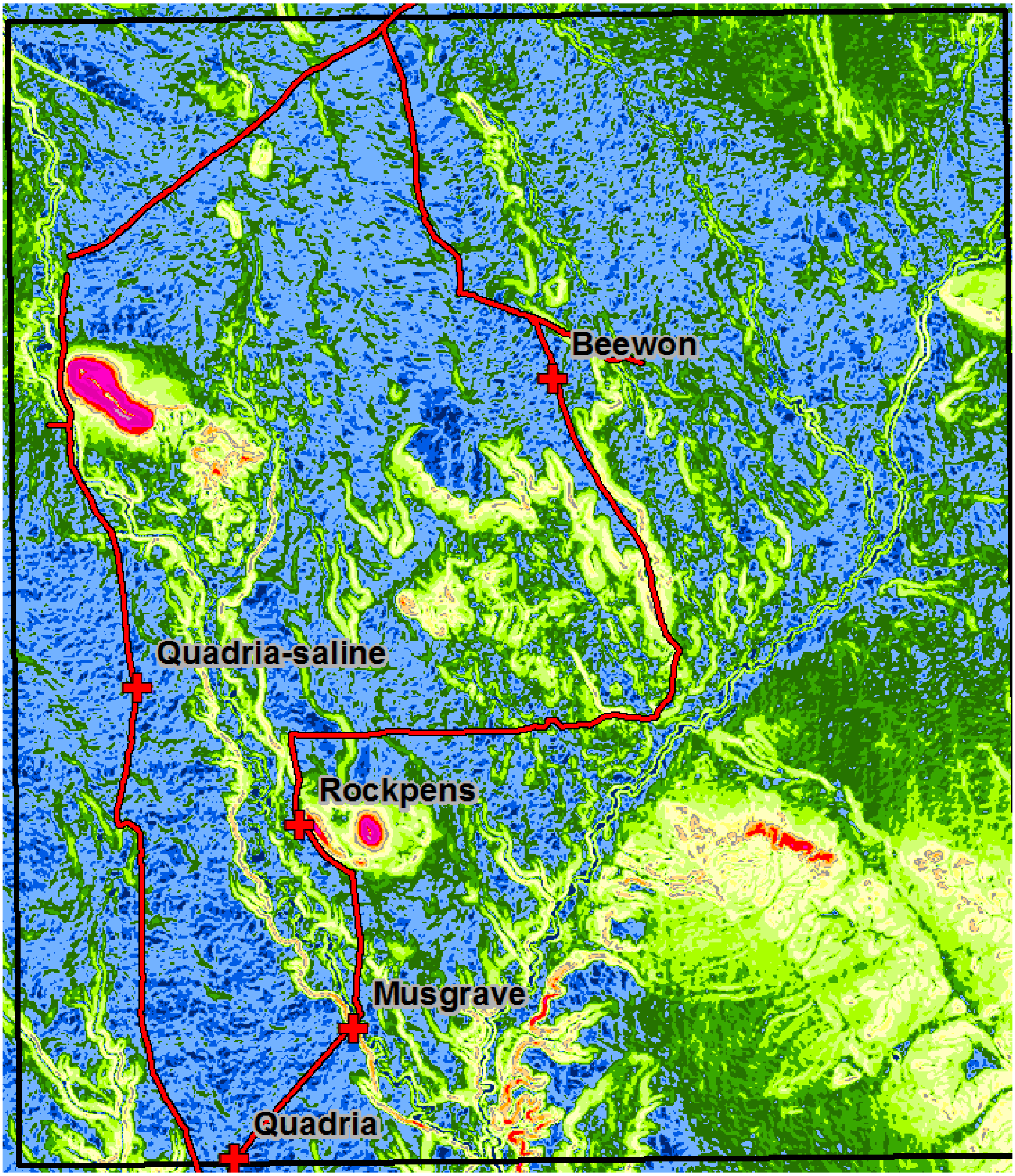
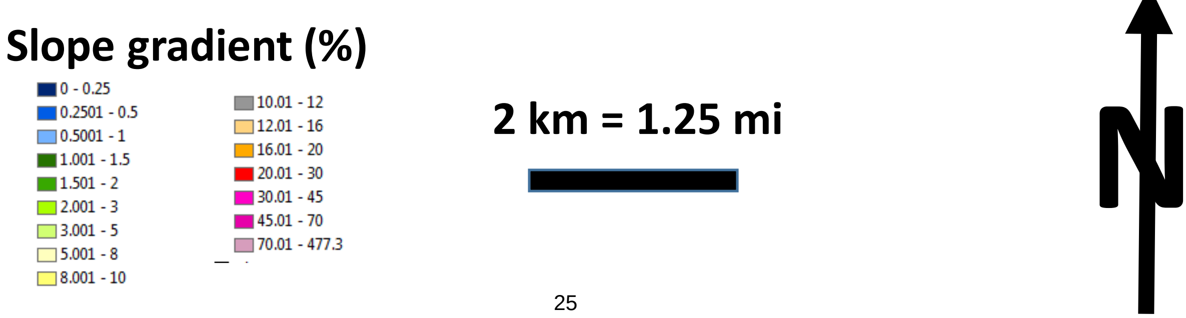


Figure 17. Slope gradient (%) within the Straddlebug Mountain quadrangle.



At this location the Loma Largo surface is 80 meters (262 feet) above base level. These pediment remnants are judged to be early-Pleistocene age, although they have similar values for height above stream as the Oligocene-age Straddlebug Mountain intrusive. Slope gradient is less than 8 percent on most Loma Largo pediment remnants.

The Quail Water alloformation is the deposit that underlies the Loma Largo surface. It is skeletal alluvium composed of ignimbrite and basalt deposited by fast-moving water. In areas downstream from carbonate bedrock it may contain fragments of limestone. Material is not well exposed and therefore not examined in detail. Soils forming in Quail Water pediment gravel are mapped Chilicotal. The soil has an ochric epipedon and a calcic horizon. Creosotebush dominates the shrub layer; abundance of understory grass depends on absolute elevation.

The Sid Place geomorphic surface is a nearly level to gently undulating pediment remnant, 1 to 2 miles southwest of the Ditch. This is the highest depositional geomorphic surface in the Straddlebug Mountain quadrangle; average height above stream is 35 meters (115 feet). Slope gradient on the Sid Place is approximately 1 percent for its entire length of 8 kilometers (5 miles). Pediment width is 0.8 to 2.5 kilometers (0.5 to 1.5 miles). Elevation on the Sid Place surface decreases from 1,177 meters (3,860 feet) at its northern edge to 1,069 meters (3,505 feet) in the south. Margins of the Sid Place surface are truncated by the Holocene-age Burnthouse Camp erosional surface.

The Black Tank pediment gravel lies beneath the Sid Place pediment surface. This allostratigraphic unit consists of skeletal, zeolitic alluvium; the fine earth is derived mainly from tuff of the Duff and Pruett Formations with rock fragments from the Mitchell Mesa ignimbrite, Cottonwood Spring basalt, and Crossen trachyte, with possible contributions from Cretaceous and Eocene limestone exposed in the watershed upstream. The alluvium can be observed on erosional scarps and was described in backhoe pits excavated on the Sid Place geomorphic surface.

The geomorphic surface and pediment gravel are judged to be at least mid-Pleistocene in age, old enough to form argillic and calcic horizons. Skeletal soils of the Beewon and Chilicotal series support a banded vegetation pattern. Sparsely vegetated interbands dominated by creosotebush alternate with narrow bands that support western honey mesquite, littleleaf sumac, and grasses. Research in Pecos County (McDonald et al., 2009) demonstrated that runoff derived from sparse interbands flows downslope to vegetated bands where it infiltrates. Ignimbrite and basalt fragments cover 2 to 70 percent of the surface. Low values of surface fragment cover are in vegetation bands; sparsely vegetated interbands have up to 70 percent fragment cover. Areas mapped “Rind” usually have greater than 50 percent fragment cover.

The Green Valley Ranch geomorphic surface is also on nearly level pediments bounded by incised drainageways (Burnthouse Camp and Oil Pad geomorphic surfaces). Southeast of McKinney Mountain, two long narrow remnants of the Green Valley Ranch pediment exist. Elevation on the eastern area decreases from 1,125 meters (3,690 feet) to 1,080 meters (3,545 feet) across a distance of 8 kilometers (5 miles). The Green Valley Ranch pediment averages 30 meters (100 feet) lower than the Sid Place surface, but average height above base level is just 11 meters (35 feet) lower. Slope gradient is 0.7 percent.

The Montgomery Lake alloformation underlies the Green Valley Ranch surface. This deposit is a fining-upward sequence; a basal layer dominated by ignimbrite fragments derived from the Mitchell Mesa (high energy deposition) is overlain by clayey zeolitic alluvium derived from the Duff Formation (low energy deposition). The alluvium is approximately 2.5 to 3 meters (8 to 10 feet) thick in exposures along Terlingua Creek. A strongly developed argillic horizon and abrupt textural change between the A and Bt1 horizons suggest a mid-Pleistocene age. Difference in clay content may result from sedimentary deposition or by clay translocation. The Quadria soil supports a diverse plant community dominated by western honey mesquite, creosotebush, Spanish dagger, and tobosa grass. Ignimbrite and basalt fragments cover from 1 to 75 percent of the soil surface. Areas mapped "Rind" usually have greater than 50 percent fragment cover.

The Plank House geomorphic surface consists of broad, nearly level alluvial flats. Mean slope gradient is 0.8 percent. The flats are usually located between the bedrock scarp around Green Valley and the older Sid Place and Green Valley Ranch surfaces. One margin of Plank House flats commonly joins a master stream: Terlingua Creek and to the Ditch. Whereas the Sid Place and Green Valley Ranch remnants are elongated parallel to the drainage network, areas of the Plank House are broad. Elevation ranges from 1,185 meters (3,890 feet) at proximal locations to 1,140 meters (3,740 feet) on distal flats. Terlingua Creek and Calamity Creek Wash are incised approximately 10 meters (32 feet) below the edge of Plank House flats.

Underlying the Plank House surface is Iron Trestle alluvium, a zeolitic clay deposit stratified in some sections. However, fine bedding planes are evident only at depths greater than 100 centimeters (40 inches). This alluvium appears to pond upslope of Goat Trap Hill. The clayey particle-size class may reflect low energy sediment depositional environment on low gradient slopes or, alternatively, in situ weathering of volcanic ash to zeolites and smectite. The mid-Pleistocene geomorphic age is inferred from the cambic, calcic, and gypsic horizons that formed the Iron Trestle clays. Martillo soils are very deep whereas Butcherknife soils are moderately deep to tuffaceous bedrock. The vegetation consists of tobosa grass with scattered low western honey mesquite shrubs.

The Eleven Section geomorphic surface is a nearly level late-Pleistocene-age stream terrace of trunk streams. The terrace rests approximately 6 meters (20 feet) above the channel and is inset approximately 5 meters (15 feet) below the adjacent Green Valley Ranch pediment. It is much less extensive than the higher, older depositional surfaces. Slope gradient of the Eleven Section surface is 1.7 percent, reflecting some post-depositional dissection.

The Sore Ribs gravel is a fining upward sequence deposited on tuffaceous bedrock. This deposit underlies the Eleven Section surface. The basal strata of extremely gravelly coarse sandy loam or loamy sand suggest a high energy sedimentary depositional environment. Ignimbrite fragments occupy 65 to 85 percent by volume of the bottom layers. Sediment particle-size fines upward to textures of loam and sandy loam near the surface and rock fragments decrease to less than 20 percent.

A late-Pleistocene age of the Sore Ribs gravel, Eleven Section geomorphic surface, and the Rockpens soil is inferred from weakly developed cambic horizons. The B horizons exhibit weak and moderate structure. Patchy carbonate coats have formed on rock fragments in skeletal zeolitic alluvium.

The O2 Ranch geomorphic surface is on nearly level alluvial flats and inset stream terraces. Geomorphic age is early- to mid-Holocene. Small areas, particularly near erosional Burnthouse Camp surfaces, may still receive alluvium. Average slope gradient is approximately 1 percent. The O2 Ranch's 11 meters (36 feet) average height above stream is greater than the older adjacent Eleven Section terrace. The O2 Ranch surface consists of stream terraces associated with master drainageways, as well as alluvial flats without defined channels. The stream terrace portion of the O2 Ranch surface is inset below the Eleven Section terrace. The alluvial flat landforms exist higher in the landscape than the stream terraces.

The Chimenea House alluvium underlying O2 Ranch alluvial flats may correlate with the Calamity Formation identified in (Albritton and Bryan, 1939). Radiocarbon dates from archaeological sites in the Green Valley area confirm early- to mid-Holocene age. This unit consists of loamy, zeolitic alluvium derived from tuffs of the Duff and Pruett Formations. Stratification and buried soil horizons are evident in many sections. Straddlebug soils with an ochric epipedon and a cambic horizon have formed in the Chimenea House alluvium.

Oil Pad geomorphic surface is the floodplain of Terlingua Creek and Calamity Creek Wash. This surface is approximately 1 meter above the stream floor. Channel floors are inundated by floodwater several times each year, but flooding frequency class of the floodplain is occasional. Average slope gradient is 1.7 percent, reflecting the walls of incised stream channels.

Paradise Draw alluvium was deposited on Oil Pad floodplains over existing paleosols. The unit ranges from 50 to 100 centimeters (20 to 40 inches) in thickness. This unit is latest-Holocene to Anthropocene in age. Derived from tuffaceous materials of the Duff and Pruett Formations, the zeolitic alluvium has a texture of fine sandy loam or loam; stratification and bedding planes are evident. Wind has formed coppice dunes in places. The Paradise Draw alluvium may correlate with the Kokernot Formation identified in (Albritton and Bryan, 1939). Nillo soils that formed in Paradise Draw alluvium contain a buried soil. Giant sacaton, alkali sacaton, western and honey mesquite dominate the vegetation. This is the most productive unit in Green Valley.

Figure 18 shows geomorphic relationships of soil components west of Straddlebug Mountain. Quadria-saline component exists on Green Valley Ranch geomorphic surface – a broad pediment. The Musgrave component is on the Holocene-age Burnthouse Camp erosional surface. On the inset Holocene-age alluvium Church Mountain geomorphic surface is the Nillo soil. Rockpens component is on Pleistocene-age Crystal Creek geomorphic surface, a fluvial terrace of Terlingua Creek. Straddlebug Mountain is capped by Tertiary-age syenite, an intrusive rock. A minimum of 97 meters (~300 feet) of geologic erosion has transpired since the emplacement of the syenite of Straddlebug Mountain during the Oligocene. The cross-sectional area of the material removed from the Green Valley Ranch geomorphic surface by Terlingua Creek since mid-Pleistocene age is approximately 6,100 m^2 (~62,000 ft^2).

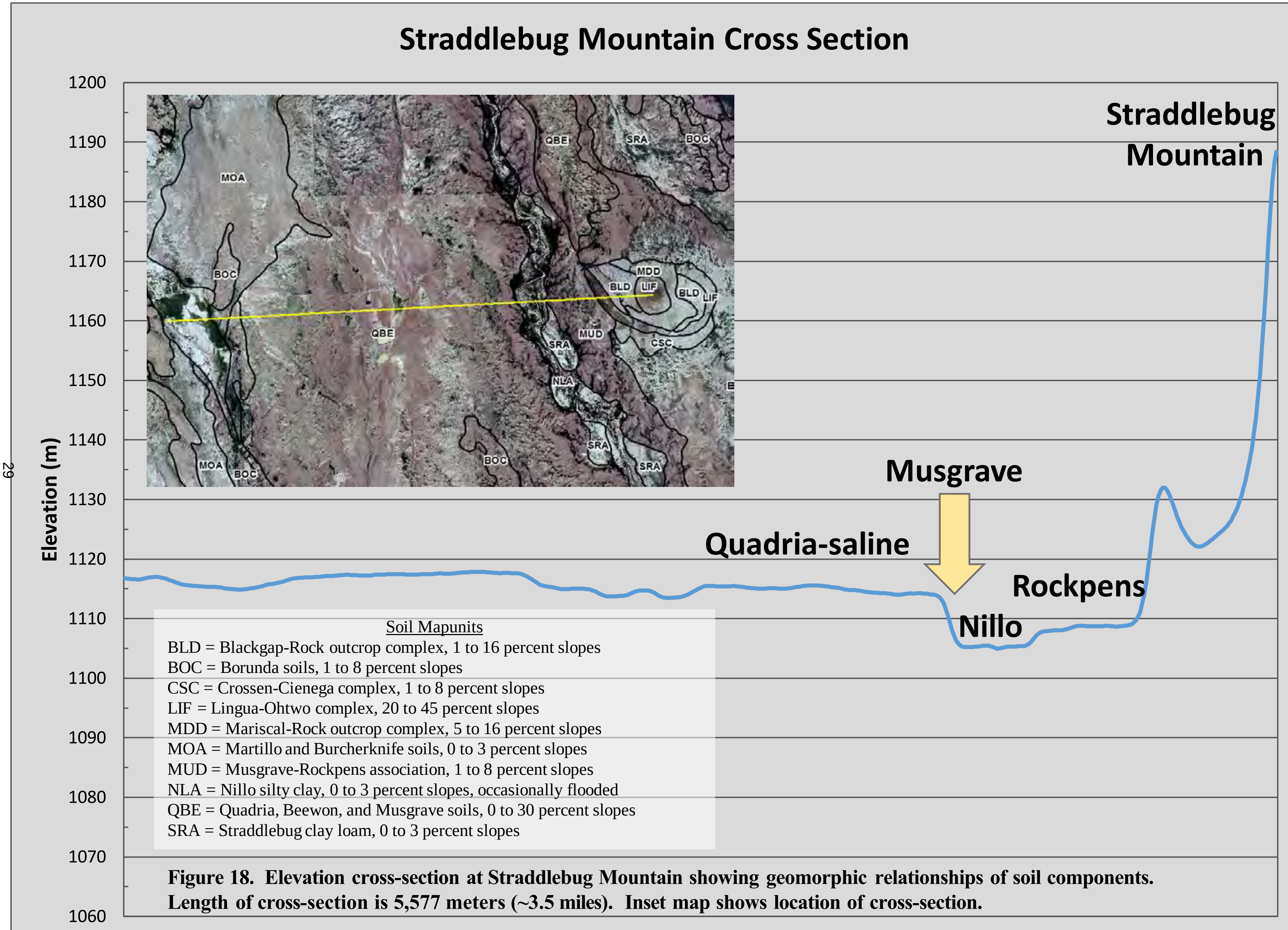


Figure 18. Elevation cross-section at Straddlebug Mountain showing geomorphic relationships of soil components. Length of cross-section is 5,577 meters (~3.5 miles). Inset map shows location of cross-section.

The Genevieve Lykes Duncan Archaeological Site

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The Genevieve Lykes Duncan (GLD) site is an open campsite on the O2 Ranch about 12 miles west of State Highway 118 at the northern edge of Green Valley. It lies in an interfluve along Terlingua Creek within the ecotone that separates the terminal foothills of the Davis Mountains and the lowland desert. The site was discovered in 2010 by the Center for Big Bend Studies (CBBS) of Sul Ross State University; test excavations (several hand-excavated 1 x 1 m units and backhoe trenches) occurred through 2012. Since that time, the CBBS has expanded their excavations into a ca. 3 x 8 m block, and a total of 13 thermal features have been uncovered that date to the Late Paleoindian period (ca. 12,200–8,500 B.P./before present). Through this work, the oldest radiocarbon date from an archaeological site in the greater Big Bend region—ca. 11,000 years old—was attained from one of the features. This work revealed two occupation intervals during the Late Paleoindian period, one from ca. 11,080–10,400 B.P. and the other from ca. 9,535–8,630 B.P.

The site derives its significance from its antiquity, the excellent preservation of the features, and the occurrence of two novel plant-food technologies in North America that subsequently became ubiquitous across the continent: 1) the use of stone as heating elements to cook select foodstuffs; and 2) grinding stones. The 11,000-year-old feature represents the earliest intact earth oven in North America, a type of cooking appliance needed to slow-cook certain plants, such as geophytes (e.g., agave, sotol, and yucca) to break down their complex sugars and make them consumable. Grinding stones were needed to grind certain plant parts, such as grass seeds, into powders that could be mixed with water to make bread-like cakes. Conjoining fragments of a metate were discovered within the 11,000-year-old oven and three different types of phytoliths (microscopic plant parts) suggestive of plant processing were identified in the laboratory: the bract material from a type of grass (Pooideae grasses), sunflower family seed hulls, and a spiderwort seed. Through these and other analyses, the site has yielded a variety of paleoenvironmental data for the early Holocene.

In light of these findings, it is possible that the unique character of the site is related to an unusually early human adaptation to a rapidly advancing aridity in the early Holocene of the Big Bend. Continued CBBS investigations at the site will undoubtedly help rewrite our understanding of the Late Paleoindian period in the Big Bend as well as contribute to state and nationwide dialogues concerning this time period.

Range Management on the O2 Ranch

Deferred Grazing
After allowing the grazing leases to expire, the Lykes Bros. Inc., decided the ranch was in an unacceptable state and began a long process of restoration. The ranch was very lightly stocked in order to allow herbaceous vegetation to recover and reestablish.

Riparian Restoration

- There have been numerous cottonwood and willow pole plantings in Terlingua Creek and Duff Springs to stabilize the soil and start bank-building on soil mapped Nillo.
- Individual western honey mesquite and salt cedar plants have also been treated using chainsaws and herbicide.
- Most riparian corridors were excluded from grazing entirely to allow the banks to revegetate.

Brush Management

- Grubbing and raking western honey mesquite on soil mapped Martillo-Butcherknife and Cesario-Fizzleflat (Figures 19 and 20).
- Spike (Tebuthiuron 20p) on creosote, tarbush, and mariola on soils mapped Chilicotal, Beewon, Paisano, Crossen-Cienaga, Stovall, Cesario-Fizzleflat, Straddlebug, Gemelo, Scotal-Ohtwo, and Borunda (Figure 21).
- Experimented with strip application to increase edge for quail habitat (Figure 22).
- Aerial and individual plant treatment using herbicide on western mesquite and salt cedar (Figure 23).
- Prescribed burning of brushy draws and tobosa/sacaton flats (Figure 24).

Restoration Research

- Study of the effects of ripping and a combination of ripping and herbicide on soil mapped Gemelo (Figure 25).
- Study of fire effects on tobosa flats on soil mapped Martillo-Butcherknife (Figure 26).
- Study of the effects of combinations of fire and herbicide on whitebrush (Aloysia gratissima).
- Study of restoration of degraded Straddlebug soils using cotton bur/burlap wattles (Figure 27).
- Study of the effects of Spike followed by prescribed fire.

Figure 19. Excavator grubbing western honey mesquite on soil mapped Martillo-Butcherknife.

Figure 20. Western honey mesquite skeletons on soil mapped Martillo-Butcherknife.

Figure 21. Air Tractor applying Spike 20p pellets.

Figure 22. Results of Spike 20p applied in strip patterns on soil mapped Chilicotal.

Figure 23. Aerial spraying western honey mesquite with herbicide on soil mapped Straddlebug.

Figure 24. Prescribed burning on soil mapped Straddlebug.

Figure 25. Restoration study of mechanical ripping on a soil mapped Gemelo.

Figure 26. Prescribed burning study on soil mapped Martillo-Butcherknife.


Figure 27. Restoration experiment of a soil mapped Straddlebug using cotton bur filled wattles.

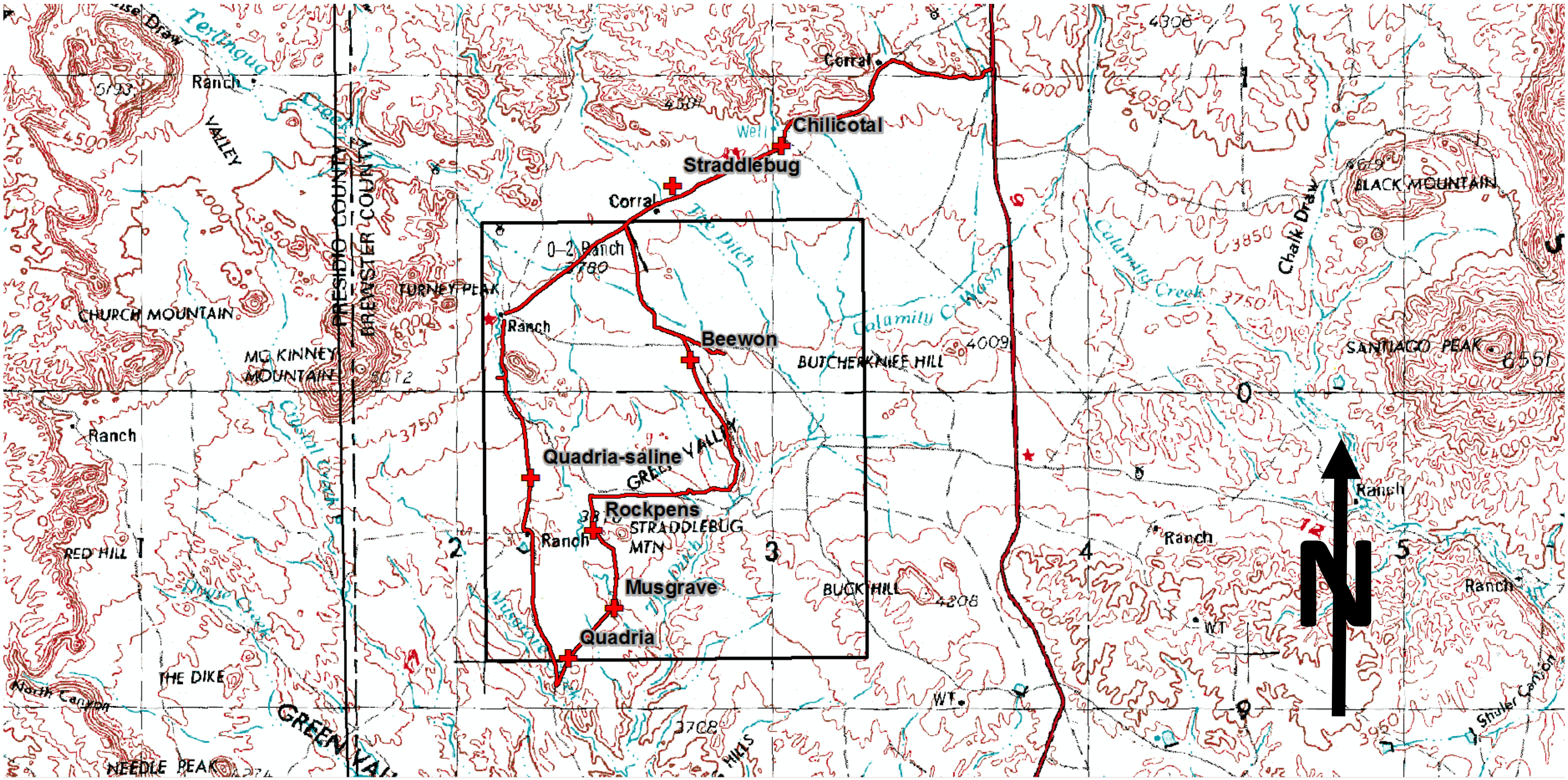

Figure 28. Overview map of Green Valley and field trip stops.

10 km = 6.2 mi

Road log

Lynn Loomis, David Jalali, Will Juett, and Shawna Graves

Mile 0.0 – Begin mileage count at Union Pacific railroad, where it crosses Texas Highway 118 S, just south of cross streets of Holland Avenue and Texas Highway 118 in Alpine.

1.1 – To the right, caliche (actually volcanic ash) pit, probably tuff of Pruett Formation.

2.6 – To the left, gate to Sierra La Rana subdivision and West Texas Natives Plant Material Center. On the eastern skyline is Bull Frog Mountain with communication towers.

3.7 – To the left, basalt exposed in road cut; high hill capped by Cottonwood Spring basalt Formation; type location of Brewster soil series.

4.3 – To the left, notice how intrusive igneous rocks weather into lumpy masses.
– Begin climbing Big Hill; Crossen trachyte exposed in roadcuts; notice manganese coats on rock surfaces.

5.7 – At powerline crossing west of road, TAMU Soil Characterization Lab pedon sampled as Brewster series, but with an argillic horizon, it really isn't Brewster.

6.3 – High point – view of Double Diamond North Subdivision, and to the left, Mount Ord.

7.1 – Grape vineyard to the right grows on Musquiz soil.
– Woodland dominated by rose-fruited juniper.

9.5 – Drainage divide between the Rio Grande River and the Pecos River watersheds.

9.6 – Mile High Road and possible Crossen trachyte in roadcut; road descends onto Cottonwood Spring basalt.

10.0 – Red argillic soil formed in Potato Hill andesite ash geological formation. Notice: concave slopes are cut into softer ash beds.

10.8 – Sign: Big Bend National Park 100 miles.

11.0 – Entrance to South Double Diamond subdivision; Soil on hills is mapped as Brewster, but with the clayey-skeletal red argillic horizon it is more likely Mainstay

11.5 – Sign: Mount Ord, 6,808 feet.

12.1 – View of Elephant Mountain. Figure 28a shows to the left, an erosion balloon on the hill. Erosion balloon is a metaphorical term for commonly obovately shaped, eroded sideslope areas that normally empty into an incised drainageway and are surrounded by noneroded sideslopes. (Peterson, 1981).

Figure 28a. View of erosion balloon.

14.0 – Sign: Cathedral Mountain, 6,800 feet; to the left, soil supporting alkali sacaton grassland is mapped Musquiz.

15.6 – To the right, Calamity Creek Road to Woodward Ranch (famous for agate). As Hwy 118 descends, we see hills of Cottonwood Spring basalt, and red alluvial clays mapped as Musquiz.

16.6 – Potato Hill andesite.

17.1 – Base of hill, Sheep Canyon basalt, volcanic ash, roadside park on left.

17.7 – To the right Crossen trachyte outcrops. Note: Highway 118 just passed through the whole geologic sequence.

18.2 – Volcanic ash in road cut.

18.4 – Culvert over Ash creek.

19.1 – To the east notice live juniper on Potato Hill andesite, but dead juniper on overlying Cottonwood Spring basalt and underlying Sheep Canyon basalt.

19.9 – To the left Sheep Canyon basalt exposed in roadcut; notice thin volcanic ash beds in Bird Hill roadcut.

20.6 – To the right is trace of Calamity Creek fault trending NW to SE; Cottonwood Spring basalt is the down-dropped footwall; Sheep Canyon Formation is the up-thrown hanging wall
– Notice "imperceptible furrows" at the hill line
– Notice volcanic ash weathers red on the south side of the fault (Figure 28b)

Figure 28b. Calamity Creek fault.

20.9 – Cottonwood and willow trees along Calamity Creek.

21.4 – Human caused stream channel diversion. The stream channel may eventually be diverted into the ditch on the west side of the road instead of flowing across the highway.

21.8 – First sighting of creosotebush on south-facing slope cutting across Sheep Canyon basalt.

22.2 – Sign: Cienega Mountain, elevation 6,562 feet.

23.1 – Volcanic ash.

23.9 – Pillow basalt exposed in roadcut to the right.

24.5 – "Yellow stuff" has the look and feel of Cretaceous bedrock; notice cottonwood and willow trees that tap groundwater discharging from perched aquifer at base of roadcut.

25.3 – Roadside park on left. Soil is mapped Straddlebug but is more like Bigetty mapped 1.6 km (1 mi) to the north. Notice burrows of ground squirrels mixing the soil. Plants include western soapberry, Arizona walnut, hackberry, and more.

26.8 – To the right, Kokernot Mesa is capped with Crossen trachyte with Pruett tuff exposed on scarp.

27.4 – Bridge over Sheep Creek, site of some of the first geoarchaeology research in United States. Type location for Neville and Kokernot Formations identified in (Albritton and Bryan, 1939). Straddlebug soils with creosotebush and tobosa grass.

28.4 – Sign: Elephant Mountain. Elevation 6,225 feet. An intrusive sill caps the mountain.

29.1 – To the left, pediment landform cuts across Pruett tuff on both sides of road.

32.0 – To the right Chino grama (fluffy clumps of grass) grows on the scarp below Kokernot Mesa.

33.9 – Trash Can Hill – Upper Cretaceous Boquillas Formation flaggy limestone with recessive softer layers, ironstone bodies and fossils (oysters, clams). Dropping from Desert Grassland into Hot Desert Shrub ecological zone.

34.6 – Entrance to O2 Ranch.

34.8 – To the right, hill underlain by flaggy limestone of the Boquillas Formation. Mariscal soil supports chino grama. To the left, thick-bedded Buda limestone and Blackgap soil. At the base of the slope and parallel to the road is the Walnut Draw fault.

37.1 – At road junction, turn left. Road to the right passes by Whirlwind Spring stage stop. To obtain water from springs, the stagecoach road from Marathon to Ciudad Chihuahua hugged the mountains.

38.6 – Boat Mountain breccia/conglomerate caprock overlies lacustrine tuff strata– conglomerate boulders strewn down the scarp. Grass and ocotillo grow on boulders. The leaves of Mormon tea, (*Ephedra aspera)* are rough to the touch.

39.9 – STOP 1. Ecological site discussion. Chilicotal soil.

Pleistocene-age alluvial fan. Rock fragments are Cottonwood Spring basalt. We have no record of how much grass grew here in the 1800's, but grass cover has not increased in 20 years

Landscape: piedmont. Landform: fan remnant

Notice calcium coated rocks brought to the surface by burrowing animals, otherwise no calcium coats on surface frags.

Notice abundant archaeology (Figure 28c).

Figure 28c. Archaeology artifacts are abundant in this area.

42.2 – STOP 2. Straddlebug type location to the north

42.5 – Former channel of The Ditch.

42.6 – Current channel of The Ditch.

43.0 – Tobosa flat on Martillo Butcherknfe undifferentiated group.

43.3 – Road climbs onto Sid Place pediment; At road fork, keep right.

44.1 – Water spreader berm.

44.4 – Water spreader berm.

44.7 – Water spreader berm.

45.6 – Water spreader berm.

46.2 – At road junction keep left; Road to right goes to Paradise Valley.

46.4 – Cross through cattle guard to bunkhouse for restroom stop.

47.0 – Flat topped McKinney Mountain is capped by Mitchell Mesa ignimbrite (overlook geomorphic surface) and Turney Peak without cap rock both underlain by tuff of Duff Formation. The resistant beds exposed on mountainside are highly cemented conglomerate.

Multiple generations of geomorphic surfaces occur on the sideslopes of McKinney Mountain; shallow soil, bare tuff outcrop, flat irons with colluvium, and erosion balloons.

47.6 – On Goat Mountain to the left, Cottonwood Spring basalt overlies tuff of the Pruett Formation.

48.0 – Rushes line Terlingua Creek. Cottonwood cuttings from Alamito Creek were transplanted here by Chris Jackson during spring 2017 (Figure 28d).

Figure 28d. Cottonwood cuttings along Terlingua Creek.

48.3 – USCGS benchmark Y738 (elevation 3,729 feet) affected by erosion; since 1943 about 13 centimeters (5 inches) of soil loss occurred.

48.1 – Holocene-age sediments overlie mid-Pleistocene-aged sediments; Holocene climbs to mid-Pleistocene.

49.3 – USCGS benchmark X738 (elevation 3,714 feet) with less than 2.5 centimeters (1 inch) erosion since 1943.

49.5 – Entering area of Quadria saline soils; vegetation is no longer dominated by creosotebush and western honey mesquite.

50.0 –Road to Terlingua Creek; begin tubercled saltbush; to the left in the middle-ground is Straddlebug Mountain and in the foreground is saline pedons.

50.3 – STOP 3. Ecological site, Quadria/saline. Tubercled saltbush, no creosotebush, no western honey mesquite, gravel veneer, physical crust on non-gravelly surfaces, notice the spongy feel to the ground.

51.3. Observe manganese coats on desert pavement, an indication of greater geomorphic age. Jackass clover with Will's "Krusty the Clown" seed heads.

54.3 – At road junction; turn left.

54.9 – STOP 4. Soil Pit, Quadria soil.

Type location for Quadria series within backhoe pit excavated in 1995. From north to south, the Green Valley Ranch pediment descends 60 meters (200 fee) elevation in 15 km (9.5 mi). Quadria is the Spanish word for packsaddle.

56.2 – STOP 5. Musgrave type location. Quaternary-age sediment gravel 2 to 3 m (6 to 10 ft) thick caps the underlying Eocene-aged tuffaceous mudstone derived from Infiernito Caldera or a source in the Davis Mountains. Musgrave soil on erosional scarp formed in residuum from tuff.

Road descends to Holocene-age stream terrace and Straddlebug soil.

55.4 – Nillo soil (possible stop if time permits, just after crossing creek). Shovel a pit to show fluvial stratification.

55.6 – Straddlebug soil again. Climb riser to Pleistocene-aged tread underlain by skeletal alluvium, Rockpens soil.

56.7 – Note exfoliation (onionskin) weathering on Straddlebug Mountain.

57.1 – STOP 6. Rockpens soil. Soil pit.

Pleistocene-age Eleven Section terrace overlooking Terlingua Creek. Soil does contain insufficient lime to qualify as calcic, but has soil structure to be cambic.

57.7 – At road junction, turn right.

58.8 – To the left, two-year-old Spike treatment on Borunda soil, gravel veneer phase; Road passes through stands of alkali sacaton that established during the past 20 years.

59.9 – At road junction, keep RIGHT (left goes to Moonscape); notice Scotal soil, shallow to calcareous white tuff with ignimbrite veneer. Reduff soil over red tuff is normally non-calcareous.

60.6 – At road junction turn LEFT.

63.3 – STOP 7. Beewon type location. Soil pit.

Banded vegetation on Beewon type location.

64.4 – Exit through rusty gates, two gates in a row, by Black Tank. Notice 2015 Spike 20p treatments.

66.6 – Back on main O2 Ranch road. Turn right to return to Alpine!

Stop 1 – Chilicotal Soil

Gravelly Ecological Site, and Herbicide Treatment

Print Date: Jul 6 2017
Description Date: Feb 28 1995
Describer: Lynn Loomis, Jerry Rives, and Alan Terrell
Site ID: S1995-TX043-112
Pedon ID: S1995-TX622-1112
Lab Pedon #: 95043-7
Soil Name: Chilicotal
Classification: Loamy-skeletal, mixed, superactive, thermic Ustic Haplocalcids

Country: United States
State: Texas
County: Brewster
MLRA: Southern Desertic Basins, Plains, and Mountains
Soil Survey Area: Brewster County, Texas (Main Part)
Std Latitude: 29.8959889
Std Longitude: -103.6513917
Latitude: 29 deg 53 min 45 sec north
Longitude: 103 deg 39 min 5 sec west
Datum: WGS84
UTM Zone: 13
UTM Easting: 630212 meters
UTM Northing: 3308024 meters
Existing Vegetation: broom snakeweed, mariola, purple pricklypear, western honey mesquite

Particle-Size Control Section: 25 to 100 cm.
Surface Fragments:
Diagnostic Features: ochric epipedon 0 to 18 cm.
calcic horizon 18 to 46 cm.

Cont. Site ID: S1995-TX043-112 **Pedon ID:** S1995-TX622-1112

Slope (%)	Elevation (meters)	Aspect (deg)	MAAT (C)	MSAT (C)	MWAT (C)	MAP (mm)	Frost-Free Days	Drainage Class	Slope Length (meters)	Upslope Length (meters)
2.0	1,201.0	150						well		

Chilicotal: Loamy-skeletal, mixed, superactive, thermic Ustic Haplocalcids

The slope gradients for Chilicotal range from 1 to 16 percent. This component is located on gently undulating to strongly rolling piedmont slopes, and formed in gravelly alluvium derived from igneous rocks. Vegetation is mainly creosotebush, tasajillo, Englemann's prickly pear, and fluffgrass. (Figure 29).

The Munsell color and the depth of the A horizon (0 to 5 cm [0 to 1.9 in]) do not meet the requirements for a mollic epipedon, therefore the epipedon is ochric.

The Bk horizon from 18 to 46 cm with 25 percent calcium carbonate equivalent qualifies as a calcic horizon.

Presence of common roots occurs to a depth of 97 cm (38.1 in). Below a depth of 97 cm (38.1 in), the occurrence of roots decreases to very few. This difference in root density may be due to an increase in rock fragment volume. In a similar pedon, the root density decreases from common to few at a depth of 71 cm (27.9 in). In this same pedon, the rock fragment volume increases from very gravelly to extremely gravelly at 71 cm (27.9 in). The very gravelly horizons are able to store more water, which may allow plants to expand their root system. The zeolitic mineralogy of this component also increases the available water capacity, thereby increasing the plant available water in the soil.

When this component was sampled in 1995, it was classified as an Ustollic Calciorthid.

The particle-size control section is from 25 to 100 cm (9.8 to 39.3 in). The CEC activity class is superactive, based on a CEC to clay ratio of 1.72.

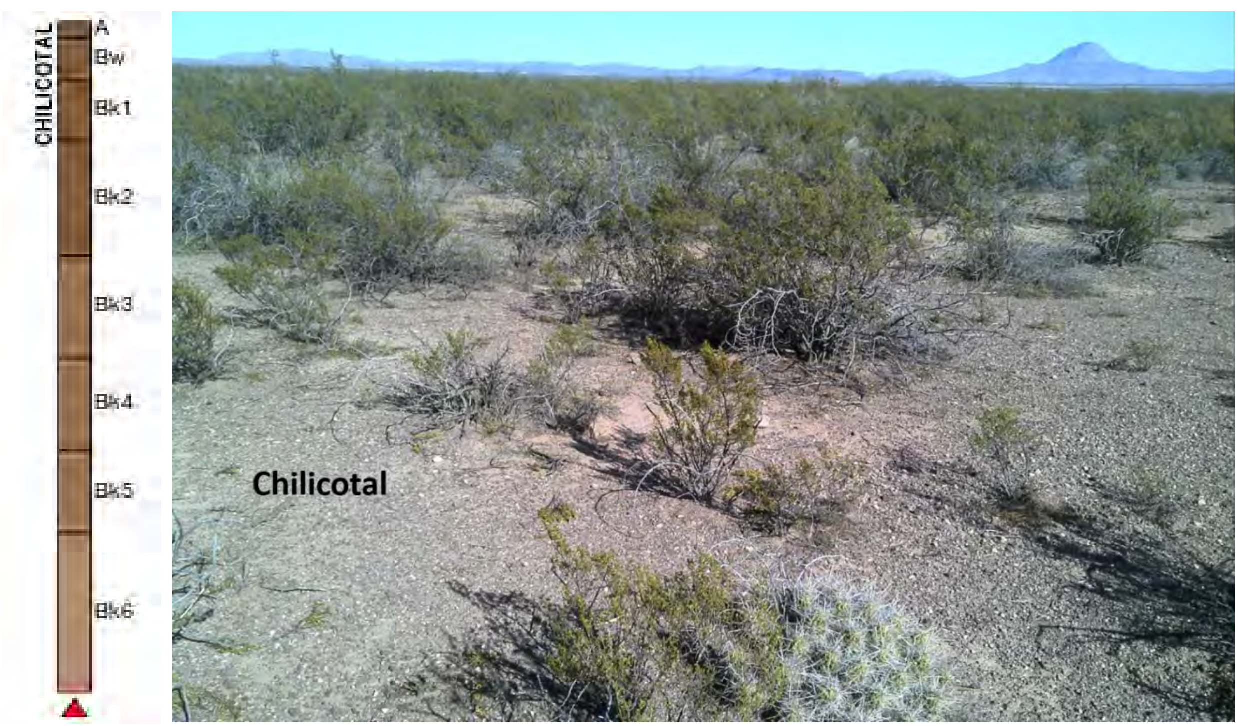

Figure 29. Piedmont landscape showing Chilicotal component forming from gravelly alluvium. Santiago Peak is visible to the east in the background. Creosotebush and pitaya can be seen in the foreground.

Stop 2 – Straddlebug Soil

Zeolites, Sodicity

Print Date: Jun 30 2017
Description Date: Mar 1 1995
Describer: Lynn Loomis, Jerry Rives, and Alan Terrell
Site ID: S1995-TX043-013-copy
Pedon ID: S1995-TX043-013-copy
Lab Source ID: SSL
Lab Pedon #: 98P0431
Classification: Fine-loamy, mixed, superactive, thermic Sodic Ustic Haplocambids
Soil Name: Straddlebug

Country: United States
State: Texas
County: Brewster
MLRA: Southern Desertic Basins, Plains, and Mountains
Soil Survey Area: Brewster County, Texas (Main Part)
Quad Name: Duff Springs, Texas
Std Latitude: 29.8850002
Std Longitude: -103.6872253
Latitude: 29 deg 53 min 6.00 sec north
Longitude: 103 deg 41 min 14.00 sec west
Datum: WGS84
UTM Zone: 13
UTM Easting: 626885 meters
UTM Northing: 3306861 meters

Existing Vegetation: alkali sacaton, American tarwort, Arizona cottontop, black grama, blue grama, burrograss, cane bluestem, creosote bush, plains bristlegrass, sand muhly, sideoats grama, tobosagrass, western honey mesquite
Parent Material: zeolitic and sodic loamy alluvium derived from tuff

Particle-Size Control Section: 25 to 100 cm.

Diagnostic Features: ochric epipedon 0 to 28 cm.
cambic horizon 28 to 200 cm.

Slope (%)	Elevation (meters)	Aspect (deg)	MAAT (C)	MSAT (C)	MWAT (C)	MAP (mm)	Frost-Free Days	Drainage Class	Slope Length (meters)	Upslope Length (meters)
1.1	1,176.5		17.6			344		well		

Straddlebug

A--0 to 10 centimeters (0.0 to 3.9 inches); pinkish gray (7.5YR 6/2) clay loam, brown (7.5YR 4/2), moist; moderate medium subangular blocky parts to weak thin platy structure; hard when dry, firm; common fine and medium roots; common very fine and fine interstitial pores; 1 percent subangular tuff gravel; violent effervescence; moderately alkaline; abrupt smooth boundary. Lab sample # 98P02492.

Ab--10 to 28 centimeters (3.9 to 11.0 inches); brown (7.5YR 5/2) clay, dark brown (7.5YR 3/2), moist; weak coarse prismatic parts to moderate medium and coarse angular blocky structure; hard when dry, firm; common very fine roots and common fine roots and common coarse roots; common very fine and fine tubular pores; 1 percent subangular tuff gravel; violent effervescence; moderately alkaline; gradual smooth boundary;

Bwb--28 to 46 centimeters (11.0 to 18.1 inches); brown (7.5YR 5/2) clay, brown (7.5YR 4/2), moist; weak coarse prismatic parts to moderate medium and coarse angular blocky structure; hard when dry, firm; common very fine and fine roots; few very fine tubular pores; 2 percent subangular tuff gravel; violent effervescence; clear smooth boundary. Lab sample # 98P02494. Also sampled as 97P0368.

Bkb1--46 to 66 centimeters (18.1 to 26.0 inches); brown (7.5YR 5/3) clay loam, brown (7.5YR 4/3), moist; weak medium and coarse subangular blocky structure; hard when dry, firm; few very fine roots; common very fine tubular pores; 1 percent prominent white (10YR 8/1) carbonate coats on ped faces; 3 percent medium carbonate masses; 5 percent subangular tuff gravel; violent effervescence; moderately alkaline; clear smooth boundary. Lab sample # 98P02495.

Bkb2--66 to 84 centimeters (26.0 to 33.1 inches); light brown (7.5YR 6/3) sandy clay loam, brown (7.5YR 5/3), moist; weak medium and coarse subangular blocky structure; hard when dry, firm; few very fine roots; common very fine and fine tubular pores; 1 percent prominent white (10YR 8/1) carbonate coats on ped faces; 3 percent fine carbonate masses; 3 percent subangular tuff gravel; violent effervescence; gradual smooth boundary. Lab sample # 98P02496.

Bkb3--84 to 117 centimeters (33.1 to 46.1 inches); light brown (7.5YR 6/3) fine sandy loam, brown (7.5YR 5/3), moist; weak medium and coarse subangular blocky structure; slightly hard, friable; few very fine roots; few very fine tubular pores; 1 percent prominent white (10YR 8/1) carbonate coats on ped faces; 3 percent medium carbonate masses; 5 percent subangular tuff gravel; violent effervescence; gradual smooth boundary. Lab sample # 98P02497.

Bkb4--117 to 147 centimeters (46.1 to 57.9 inches); light brown (7.5YR 6/3) fine sandy loam, brown (7.5YR 5/3), moist; weak medium and coarse subangular blocky structure; slightly hard, friable; few very fine roots; few very fine tubular pores; 1 percent prominent white (10YR 8/1) carbonate coats on ped faces; 3 percent medium carbonate masses; 5 percent subangular tuff gravel; violent effervescence; moderately alkaline; gradual smooth boundary.

Bkb5--147 to 203 centimeters (57.9 to 79.9 inches); light brown (7.5YR 6/3) clay loam, brown (7.5YR 5/3), moist; weak medium and coarse subangular blocky structure; slightly hard, firm; few very fine roots; few very fine tubular pores; 1 percent prominent white (10YR 8/1) carbonate coats on ped faces; 3 percent medium carbonate masses; 2 percent subangular tuff gravel; violent effervescence. Lab sample # 98P02499.

*** Primary Characterization Data ***

Pedon ID: S1995-TX043-013-copy | (Brewster, Texas) | Print Date: Jun 27 2017 9:09AM

Sampled as : Straddlebug ; Fine-loamy, mixed, superactive, thermic Sodic Ustic Haplocambid
Revised to correlated on Jan 30, 2013: Straddlebug ; Fine-loamy, mixed, superactive, thermic Sodic Ustic Haplocambids

SSL - Project CP98TX119 BREWSTER COUNTY
- Site ID S1995-TX043-013-copy Lat: 29° 53' 6.00" north Long: 103° 41' 14.01" west MLRA: 42
- Pedon No. 98P0431
- General Methods 1B1A, 2A1, 2B

United States Department of Agriculture
Natural Resources Conservation Service
National Soil Survey Center
Soil Survey Laboratory
Lincoln, Nebraska 68508-3866

Layer	Horizon	Orig Hzn	Depth (cm)	Field Label 1	Field Label 2	Field Label 3	Field Texture	Lab Texture
98P02492	A1	A1	0-10				SICL	CL
98P02493	A2	A2	10-28				CL	C
98P02494	Bn	BN	28-46				CL	C
98P02495	Bkn1	BkN1	46-66				CL	CL
98P02496	Bkn2	BkN2	66-84				SCL	SCL
98P02497	Bkn3	BkN3	84-117				SL	FSL
98P02498	Bkn4	BkN4	117-147				SL	FSL
98P02499	Bkn5	BkN5	147-203				SCL	CL

PSDA & Rock Fragments

Layer	Depth (cm)	Horz	Prep	-1- Lab Texture	-2- Clay < .002 (Total)	-3- Silt .002 -.05 (Total)	-4- Sand .05 -2 (Total)	-5- Fine Clay < .0002	-6- CO_3 Clay < .002	-7- Fine Silt .002 -.02	-8- Coarse Silt .02 -.05	-9- VF Sand .05 -.10	-10- F Sand .10 -.25	-11- M Sand .25 -.50	-12- C Sand .5 -1	-13- VC Sand 1 -2	-14- Rock Fragments Weight 2 -5	-15- Rock Fragments Weight 5 -20	-16- Rock Fragments Weight 20 -75	-17- Rock Fragments Weight .1- 75	-18- >2 mm wt % whole soil
					(- % of <2mm Mineral Soil											- -)	(- - - - - - - % of <75mm			- - - - - -)	
				3A1a1a	3A1a1a	3A1a1a	3A1a1a		3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3B1	3B1	3B1		
98P02492	0-10	A1	S	cl	34.5	43.8	21.7		1.0	33.2	10.6	6.9	6.1	3.3	2.8	2.6	3	2	--	19	5
98P02493	10-28	A2	S	c	44.5	25.2	30.3		7.2	17.7	7.5	7.6	10.1	6.2	3.8	2.6	4	1	--	27	5
98P02494	28-46	Bn	S	c	41.8	27.7	30.5		8.6	19.6	8.1	8.9	10.5	5.5	3.4	2.2	2	1	--	24	3
98P02495	46-66	Bkn1	S	cl	29.5	28.9	41.6		4.6	17.4	11.5	15.8	14.0	4.5	3.3	4.0	8	4	--	35	12
98P02496	66-84	Bkn2	S	scl	21.5	26.7	51.8		3.5	16.1	10.6	15.1	16.0	7.5	6.7	6.5	10	4	--	46	14
98P02497	84-117	Bkn3	S	fsl	13.6	20.5	65.9		1.0	10.2	10.3	22.2	22.6	8.8	6.3	6.0	8	3	--	50	11
98P02498	117-147	Bkn4	S	fsl	15.1	25.0	59.9		1.3	13.1	11.9	22.6	22.6	7.8	4.5	2.4	4	3	--	42	7
98P02499	147-203	Bkn5	S	cl	27.9	28.0	44.1		4.1	17.4	10.6	13.7	14.6	6.8	5.0	4.0	13	6	4	46	23

Bulk Density & Moisture

Layer	Depth (cm)	Horz	Prep	-1- Bulk Density 33 kPa (g cm^{-3})	-2- Bulk Density Oven Dry (g cm^{-3})	-3- Cole Whole Soil	-4- Water Content 6 kPa	-5- Water Content 10 kPa	-6- Water Content 33 kPa	-7- Water Content 1500 kPa	-8- Water Content 1500 kPa Moist	-9- Ratio AD/OD	-10- WRD Whole Soil cm^3 cm^{-3}	-11- Aggst Stabl 2-0.5mm %	-12- Ratio/Clay CEC7	-13- Ratio/Clay 1500 kPa
							(- - - - - - - - - - - - % of < 2mm				- - - - - - - - - - - -)					
										3C2a1a		3D1		3F1a1a	8D1	8D1
98P02492	0-10	A1	S							14.0		1.036		28	0.87	0.41
98P02493	10-28	A2	S							15.1		1.037			0.66	0.34
98P02494	28-46	Bn	S							16.1		1.034			0.66	0.39
98P02495	46-66	Bkn1	S							12.8		1.027			0.78	0.43
98P02496	66-84	Bkn2	S							10.0		1.021			0.90	0.47
98P02497	84-117	Bkn3	S							7.7		1.017			1.28	0.57
98P02498	117-147	Bkn4	S							8.2		1.018			1.16	0.54
98P02499	147-203	Bkn5	S							12.8		1.025			0.78	0.46

*** Primary Characterization Data ***

Pedon ID: S1995-TX043-013-copy | (Brewster, Texas) | Print Date: Jun 27 2017 9:09AM

Sampled As : Straddlebug | Fine-loamy, mixed, superactive, thermic Sodic Ustic Haplocambid

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 98P0431

Carbon & Extractions

Layer	Depth (cm)	Horz	Prep	-1- Total C	-2- Total N	-3- Total S	-4- Est OC	-5- OC (WB)	-6- C/N Ratio	-7- Dith-Cit Ext Fe	-8- Dith-Cit Ext Al	-9- Dith-Cit Ext Mn	-10- Al+½Fe	-11- ODOE	-12- Ammonium Oxalate Fe	-13- Al	-14- Si	-15- Mn	-16- Na Pyro-Phosphate C	-17- Fe	-18- Al	-19- Mn
				(- - - - - - - - - % of <2 mm - - - - - - - - - -)						(- - - - - - - - % of < 2mm								mg kg^{-1}	(- - - - - % of < 2mm - - - - -)			
				6A2e	6B4a																	
98P02492	0-10	A1	S	1.63	0.139		1.1															
98P02493	10-28	A2	S	2.11	0.100		0.7															
98P02494	28-46	Bn	S	2.16	0.071		0.4															
98P02495	46-66	Bkn1	S	1.82	0.058		0.2															
98P02496	66-84	Bkn2	S	1.69	0.040		0.1															
98P02497	84-117	Bkn3	S	1.13	0.028		tr															
98P02498	117-147	Bkn4	S	1.21			--															
98P02499	147-203	Bkn5	S	1.32			tr															

[1,1,2,3,4,5,6,7] Analyzed size fraction = <2 mm

CEC & Bases

Layer	Depth (cm)	Horz	Prep	-1- NH$_4$OAC Extractable Bases Ca	-2- Mg	-3- Na	-4- K	-5- Sum Bases	-6- Acidity	-7- Extr Al	-8- KCl Mn	-9- CEC8 Sum Cats	-10- CEC7 NH$_4$ OAC	-11- ECEC Bases +Al	-12- Al Sat	-13- Base Saturation Sum	-14- Base Saturation NH$_4$OAC
				(- - - - - - - - - cmol(+) kg^{-1} - - - - - - - - -)							mg kg^{-1}	(- - - - cmol(+) kg^{-1} - - -)			(- - - - - - - - % - - - - - - - -)		
				6N2i	6O2h	6P2f	6Q2f		6H5a				5A8b			5C3	5C1
98P02492	0-10	A1	S	58.6*	1.7	1.3	2.2		--				30.0			100	100
98P02493	10-28	A2	S	59.8*	1.3	5.0	1.5						29.2			100	100
98P02494	28-46	Bn	S	57.3*	1.3	8.2	0.5						27.7			100	100
98P02495	46-66	Bkn1	S	51.5*	1.0	9.8	0.7						23.0			100	100
98P02496	66-84	Bkn2	S	47.7*	0.8	9.4	0.7						19.4			100	100
98P02497	84-117	Bkn3	S	44.1*	0.6	10.0	0.7						17.4			100	100
98P02498	117-147	Bkn4	S	51.1*	0.6	10.2	0.7						17.5			100	100
98P02499	147-203	Bkn5	S	48.9*	0.8	11.3	0.8						21.7			100	100

*Extractable Ca may contain Ca from calcium carbonate or gypsum. CEC7 base saturation set to 100.

Salt

Layer	Depth (cm)	Horz	Prep	-1- Ca	-2- Mg	-3- Na	-4- K	-5- CO$_3$	-6- HCO$_3$	-7- F	-8- Cl	-9- PO$_4$	-10- Br	-11- OAC	-12- SO$_4$	-13- NO$_2$	-14- NO$_3$	-15- H$_2$O	-16- Total Salts	-17- Elec Cond	-18- 1:2 Elec Cond	-19- Exch Na	-20- SAR
				(- - - - - - - - - - - Water Extracted From Saturated Paste - - - - - - - - - - -)																			
				(- - - - - mmol(+) L^{-1} - - - - -)				(- - - - - - - - mmol(-) L^{-1} - - - - - - - -)										(- - - % - - -)		(- - dS m^{-1} - -)		%	
				6N1d	6O1d	6P1d	6Q1d	6I1b	6J1b	6U1c	6K1e				6L1e	6W1c	6M1e	8A	8D5	8A3a	4F1a1a1		5E
98P02492	0-10	A1	S	4.5	0.3	2.9	0.4	--	7.2	tr	0.2				0.4	tr	tr	52.4	tr	0.78	0.34	4	2
98P02493	10-28	A2	S	0.7	--	8.1	0.1	--	7.1	tr	0.7				0.6	tr	tr	53.4	tr	0.86	0.39	16	14
98P02494	28-46	Bn	S	0.7		14.3	0.1	--	5.7	0.1	6.6				1.5	--	tr	56.4	0.1	1.48	0.66	27	24
98P02495	46-66	Bkn1	S	1.0	0.1	20.0	0.1	--	4.3	0.2	12.0				3.6	--	0.1	51.3	0.1	2.19	1.03	38	27
98P02496	66-84	Bkn2	S	1.9	0.1	33.2	0.1	--	3.6	0.2	20.6				8.0	--	0.2	40.4	0.1	3.67	1.15	42	33
98P02497	84-117	Bkn3	S																		1.36	57	
98P02498	117-147	Bkn4	S																		2.75	58	
98P02499	147-203	Bkn5	S																		1.45	52	

Pedon ID: S1995-TX043-013-copy (Brewster, Texas) Print Date: Jun 27 2017 9:09AM

Sampled As : Straddlebug Fine-loamy, mixed, superactive, thermic Sodic Ustic Haplocambid

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 98P0431

pH & Carbonates

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-
				(- - - - pH					- - - -)	(- - Carbonate - -) As $CaCO_3$		(- - Gypsum - - -) As $CaSO_4*2H_2O$		
Layer	Depth (cm)	Horz	Prep	KCl	$CaCl_2$ 0.01M 1:2	H_2O 1:1	Sat Paste	Oxid	NaF	<2mm	<20mm	<2mm	<20mm	Resist ohms cm^{-1}
										(- - - - %			- - - -)	
					4C1a2a	4C1a2a	8C1b			4E1a1a1a1		4E2a1a1a1		
98P02492	0-10	A1	S		7.8	8.4	7.7			5				
98P02493	10-28	A2	S		8.1	8.7	8.1			12				
98P02494	28-46	Bn	S		8.3	8.8	7.9			14		--		
98P02495	46-66	Bkn1	S		8.3	8.8	7.9			13		--		
98P02496	66-84	Bkn2	S		8.0	8.8	8.0			13		--		
98P02497	84-117	Bkn3	S		8.1	8.8				9		--		
98P02498	117-147	Bkn4	S		8.0	8.3				11		--		
98P02499	147-203	Bkn5	S		8.4	8.7				11		--		

Clay Mineralogy (<.002 mm)

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-
				X-Ray						Thermal			Elemental							EGME	Inter
													SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Na_2O	Retn	preta
	Depth		Fract	7A2i																	tion
Layer	(cm)	Horz	ion	(- - - - peak size				- - - -)	(- - - - %			- - - -)	(- - - - %						- - - -)	mg g^{-1}	
98P02493	10.0-28.0	A2	tcly	CA 3	MT 2	QZ 2															
98P02495	46.0-66.0	Bkn1	tcly	MT 2	CA 2	QZ 2															
98P02497	84.0-117.0	Bkn3	tcly	MT 3	CA 2	QZ 1															

FRACTION INTERPRETATION:

tcly - Total Clay <0.002 mm

MINERAL INTERPRETATION:

CA Calcite MT Montmorillonite QZ Quartz

RELATIVE PEAK SIZE: 5 Very Large 4 Large 3 Medium 2 Small 1 Very Small 6 No Peaks

*** Primary Characterization Data ***

Pedon ID: S1995-TX043-013-copy (Brewster, Texas) Print Date: Jun 27 2017 9:09AM

Sampled As : Straddlebug Fine-loamy, mixed, superactive, thermic Sodic Ustic Haplocambid

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 98P0431

Sand - Silt Mineralogy (2.0-0.002 mm)				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-
						X-Ray					Thermal					Optical				EGME	Inter
													Tot Re			Grain Count				Retn	preta
	Depth		Fract													7B1a2					tion
Layer	(cm)	Horz	ion	(- - - - - - - - peak size - - - - - - - - -)					(- - - - - - - - % - - - - - - - - - -)				(- - - - - - - - - - - - - - - - - - - % - - - - - - - - - - - - - - - - - -)							mg g^{-1}	
98P02493	10.0-28.0	A2	fs										35	AR 21	FK 21	QZ 19	FP 13	FE 10	CD 5		
														CA 5	ZE 4	CB 2	OP 1	GS tr	FF tr		
														BT tr							
98P02495	46.0-66.0	Bkn1	fs										27	AR 19	FK 18	FP 17	QZ 14	CA 8	FE 7		
														ZE 6	CD 5	CB 3	GS 2	OP 1	FF tr		
														BT tr							
98P02497	84.0-117.0	Bkn3	fs										22	AR 21	FK 16	FP 15	CA 12	QZ 11	ZE 7		
														FE 5	CB 4	CD 4	GS 3	OP 2	FF tr		
														BT tr							

FRACTION INTERPRETATION:

fs - Fine Sand 0.1-0.25 mm

MINERAL INTERPRETATION:

AR Weatherable Aggregates	BT Biotite	CA Calcite	CB Carbonate Aggregates	CD Chert (Chalcedony
FE Iron Oxides (Goethite	FF Foraminifera	FK Potassium Feldspar	FP Plagioclase Feldspar	GS Glass
OP Opaques	QZ Quartz	ZE Zeolite		

Straddlebug: Fine-loamy, mixed, superactive, thermic Sodic Ustic Haplocambids

The slope gradients for Straddlebug range from 0 to 3 percent. This component is located on broad alluvial flats and terraces, and formed in sodic loamy alluvium derived mainly from tuffs of the Duff and Pruett Formations. Vegetation is mainly western honey mesquite, tarbush, creosotebush, and alkali sacaton.

The Munsell color and the depth of the A horizon (0 to 10 centimeters [0.0 to 3.9 inches]) do not meet the requirements for a mollic epipedon, therefore the epipedon is ochric. A cambic horizon can be found between the depths of 28 to 203 centimeters (11.0 to 79.9 inches) (Bn and Bkn horizons), based on the evidence of presence of soil structure and higher value and chroma than overlying horizons.

This soil has a sodic feature, due to a sodium adsorption ratio (SAR) of greater than 13 in a horizon at least 25 centimeters (9.8 inches) thick within 100 centimeters (39.3 inches) of the surface (Bn, Bkn1, and Bkn2 horizons). This soil also has a fluventic feature, due to an irregular decrease in organic carbon with increasing depth. This is evidence of disparate alluvial deposition events, with varying amounts of organic material being deposited at different times and strata in the profile.

Common roots are described to a depth of 46 centimeters (18.1 inches). Below a depth of 46 centimeters (18.1 inches), the occurrence of roots decreases to few. This difference in root density may be due to a change in soil horizon textures from clays, to clay loam and sandy clay loam. The clays are able to store more water, which may allow plants to expand their root system. The zeolitic mineralogy of this component also increases the available water capacity, thereby increasing the plant available water in the soil.

There was a classification change from Ustifluventic Haplocambids to Sodic Ustic Haplocambids based on TAMU laboratory data (S93TX-377-007) from Presidio County, Texas, and a NSSL reference sample (S95TX-043-013) from the type location in Brewster County, Texas.

The particle-size control section is from 25 to 100 centimeters (9.8 to 39.3 inches). The CEC activity class is superactive, based on a CEC to clay ratio of 1.03.

Figure 30. Alluvial flat landscape with Straddlebug component forming from sodic loamy alluvium. Alkali sacaton and fourwing saltbush are visible in the foreground.

Stop 3 – Quadria-Saline Soil

Salty Ecological Site

Figures 31, 32, 33, and 34 show the soil structure and vegetation of the Quadria-saline site.

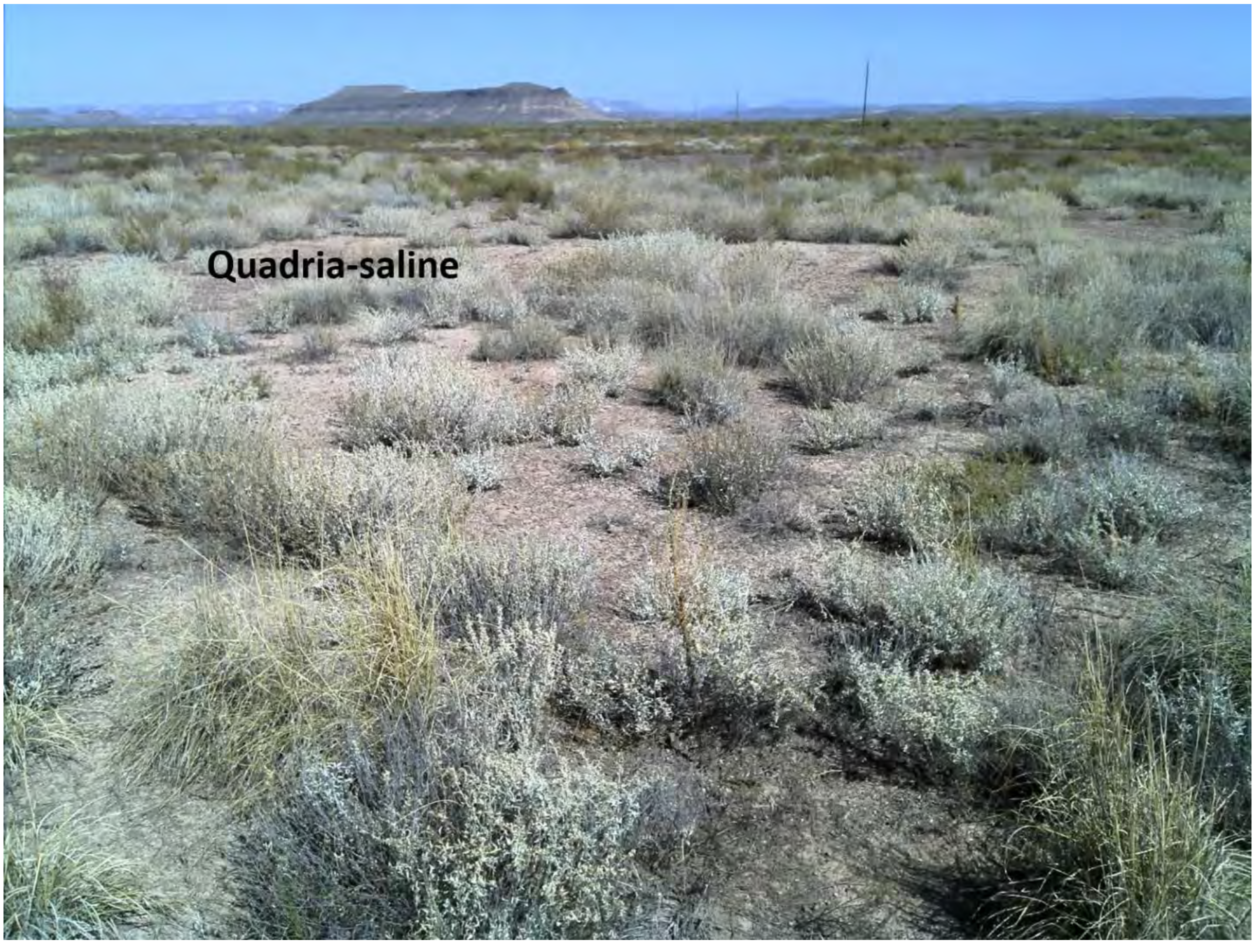

Figure 31. Pediment landscape showing Quadria-saline soil forming in moderately saline clayey alluvium. Goat Mountain can be seen to the north, with Mitchell Mesa appearing on the far skyline in the background. Tubercled saltbush, desert seepweed, fourwing saltbush, and alkali sacaton are visible in the foreground.

Figure 32. Shown are different soil structures of the Quadria-saline component.

Figure 33. Another view of the Green Valley Ranch pediment with Goat Mountain in the background on the right, Turney Peak to the left, and Mitchell Mesa on the skyline.

Figure 34. Close-up of seep weed (*Suaeda suffrutescens*) on Quadria-saline soil.

Stop 4 – Quadria Soil

Clay Loam Pediment Ecological Site

Print Date: Jun 29 2017
Description Date: Mar 3 1995
Describer: Lynn Loomis, Jerry Rives, and Alan Terrell
Site ID: S1995-TX043-023-copy
Pedon ID: S1995-TX043-023-copy
Lab Source ID: SSL
Lab Pedon #: 98P0428
Soil Name: Quadria
Classification: Fine, mixed, superactive, thermic Ustic Natrargids

Country: United States
State: Texas
County: Brewster
MLRA: Southern Desertic Basins, Plains, and Mountains
Soil Survey Area: Brewster County, Texas (Main Part)
Quad Name: Long Hills, Texas
Std Latitude: 29.7507380
Std Longitude: -103.7227580
Latitude: 29 deg 45 min 2.66 sec north
Longitude: 103 deg 43 min 21.93 sec west
Datum: WGS84
UTM Zone: 13
UTM Easting: 623499 meters
UTM Northing: 3291849 meters
Primary Earth Cover: Grass/herbaceous cover
Secondary Earth Cover: Grassland rangeland
Existing Vegetation: American tarwort, black grama, blue grama, burrograss, bush muhly, creosote bush, fourwing saltbush, plains bristlegrass, sideoats grama, tobosagrass, western honey mesquite

Particle-Size-Control Section: 13 to 63 cm.
Diagnostic Features:
ochric epipedon 0 to 13 cm.
argillic horizon 13 to 117 cm.
natric horizon 13 to 117 cm.
calcic horizon 43 to 117 cm.

Top Depth (cm)	Bottom Depth (cm)	Restriction Kind	Restriction Hardness
13	13	abrupt textural change	Noncemented
13	117	natric	Noncemented

Slope (%)	Elevation (meters)	Aspect (deg)	MAAT (C)	MSAT (C)	MWAT (C)	MAP (mm)	Frost-Free Days	Drainage Class	Slope Length (meters)	Upslope Length (meters)
0.3	1,096.6	180	18.5			321		well		

Quadria

A--0 to 13 centimeters (0.0 to 5.1 inches); brown (7.5YR 5/3) loam, dark brown (7.5YR 3/3), moist; moderate fine and medium subangular blocky structure; common very fine and fine roots throughout and common medium and coarse roots throughout; common very fine and fine low-continuity tubular pores; 5 percent subrounded ignimbrite gravel; slight effervescence; abrupt smooth boundary.

Bt--13 to 28 centimeters (5.1 to 11.0 inches); reddish brown (5YR 5/3) clay, reddish brown (5YR 4/3), moist; moderate coarse prismatic parts to moderate medium and coarse subangular blocky parts to moderate fine and medium subangular blocky structure; common very fine and fine roots throughout and common medium and coarse roots throughout; common very fine and fine low-continuity tubular and common medium moderate-continuity tubular pores; 70 percent distinct reddish brown (5YR (5/3), dry, clay films on ped faces; strong effervescence; clear smooth boundary.

Btn--28 to 43 centimeters (11.0 to 16.9 inches); reddish brown (5YR 5/3) clay, reddish brown (5YR 4/3), moist; moderate coarse prismatic parts to moderate medium and coarse subangular blocky parts to moderate fine and medium subangular blocky structure; common very fine and fine roots throughout and common medium roots throughout; common very fine and fine low-continuity tubular pores; 60 percent distinct reddish brown (5YR 5/3), dry, clay films on ped faces; 2 percent subangular ignimbrite gravel; violent effervescence; clear smooth boundary.

2Btkn2--61 to 79 centimeters (24.0 to 31.1 inches); light reddish brown (5YR 6/4) very gravelly clay loam, reddish brown (5YR 5/4), moist; weak medium and coarse subangular blocky parts to weak fine and medium subangular blocky structure; common very fine and fine roots throughout; few very fine and fine low-continuity tubular pores; 3 percent distinct white (10YR 8/1), dry, carbonate coats on ped faces and 20 percent distinct white (10YR 8/1), dry, carbonate coats on lower ped faces or rocks; 3 percent coarse irregular white (10YR 8/1) carbonate masses throughout and 7 percent medium irregular white (10YR 8/1) carbonate masses throughout; 30 percent rounded ignimbrite gravel and 10 percent subrounded ignimbrite cobbles; violent effervescence; gradual smooth boundary.

2Btkn3--79 to 117 centimeters (31.1 to 46.1 inches); light reddish brown (5YR 6/4) very gravelly sandy clay loam, reddish brown (5YR 5/4), moist; weak medium and coarse subangular blocky parts to weak fine and medium subangular blocky structure; few very fine and fine roots throughout; few very fine and fine low-continuity tubular pores; 2 percent distinct white (10YR 8/1), dry, carbonate coats on ped faces and 15 percent distinct white (10YR 8/1), dry, carbonate coats on rock fragments; 4 percent coarse irregular white (10YR 8/1) carbonate masses throughout and 2 percent medium irregular white (10YR 8/1) carbonate masses throughout; 30 percent rounded ignimbrite gravel and 5 percent subrounded ignimbrite cobbles; noneffervescent; clear smooth boundary.

2Btkn3--79 to 117 centimeters (31.1 to 46.1 inches); light reddish brown (5YR 6/4) very gravelly sandy clay loam, reddish brown (5YR 5/4), moist; weak medium and coarse subangular blocky parts to weak fine and medium subangular blocky structure; few very fine and fine roots throughout; few very fine and fine low-continuity tubular pores; 2 percent distinct white (10YR 8/1), dry, carbonate coats on ped faces and 15 percent distinct white (10YR 8/1), dry, carbonate coats on rock fragments; 4 percent coarse irregular white (10YR 8/1) carbonate masses throughout and 2 percent medium irregular white (10YR 8/1) carbonate masses throughout; 5 percent subrounded ignimbrite cobbles and 30 percent rounded ignimbrite gravel; noneffervescent; clear smooth boundary.

3Bkn--117 to 145 centimeters (46.1 to 57.1 inches); light reddish brown (5YR 6/3) fine sandy loam, reddish brown (5YR 5/3), moist; weak fine and medium subangular blocky structure; few very fine and fine roots throughout; few very fine and fine low-continuity tubular pores; 4 percent coarse irregular white (10YR 8/1) carbonate masses throughout and 3 percent medium irregular white (10YR 8/1) carbonate masses throughout; 5 percent rounded ignimbrite gravel; noneffervescent; clear smooth boundary.

3BCkn--145 to 200 centimeters (57.1 to 78.7 inches); reddish brown (5YR 5/3) gravelly coarse sandy loam, reddish brown (5YR 4/3), moist; weak fine and medium subangular blocky structure; very few very fine and fine roots throughout; few very fine and fine low-continuity tubular pores; 2 percent distinct white (10YR 8/1), dry, carbonate coats on ped faces and 5 percent distinct white (10YR 8/1), dry, carbonate coats on rock fragments; 3 percent coarse irregular white (10YR 8/1) carbonate masses throughout and 1 percent medium irregular white (10YR 8/1) carbonate masses throughout; 20 percent rounded ignimbrite gravel and 10 percent subrounded ignimbrite cobbles; noneffervescent; alternating strata of coarse sand and very gravelly coarse sand 6 inches thick.

*** Primary Characterization Data ***

Pedon ID: S1995-TX043-023-copy

(Brewster, Texas)

Print Date: Jun 27 2017 9:59AM

Sampled as on Mar 1, 1995: Quadria ; Fine, mixed, superactive, thermic Ustic Natrargids
Revised to correlated on Apr 3, 2016: Quadria ; Fine, mixed, superactive, thermic Ustic Natrargids

United States Department of Agriculture
Natural Resources Conservation Service
National Soil Survey Center
Soil Survey Laboratory
Lincoln, Nebraska 68508-3866

SSL - Project CP98TX119 BREWSTER COUNTY
- Site ID S1995-TX043-023-copy Lat: 29° 45' 2.66" north Long: 103° 43' 21.93" west MLRA: 42
- Pedon No. 98P0428
- General Methods 1B1A, 2A1, 2B

Layer	Horizon	Orig Hzn	Depth (cm)	Field Label 1	Field Label 2	Field Label 3	Field Texture	Lab Texture
98P02474	A	A	0-13				L	L
98P02475	Btn1	Btn1	13-28				C	C
98P02476	Btn2	Btn2	28-43				C	C
98P02477	Btkn1	BtkN1	43-61				C	CL
98P02478	Btkn2	BtkN2	61-79				CL	L
98P02479	Btkn3	BtkN3	79-117				SCL	SCL
98P02480	2Bkn	2BkN	117-145				SL	FSL
98P02481	3BCkn	3BCkN	145-203				SL	LCOS

PSDA & Rock Fragments

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-
					(- - - - - Total - - - - - -)			(- - Clay - - -)		(- - - - Silt - - - - -)		(- - - - - - - - - - - - Sand - - - - - - - - - - - -)					(Rock Fragments (mm))				
				Lab	Clay	Silt	Sand	Fine	CO₃	Fine	Coarse	VF	F	M	C	VC	(- - - - - - - - Weight - - - - - - - -)				>2 mm
				Text-	<	.002	.05	<	<	.002	.02	.05	.10	.25	.5	1	2	5	20	.1-	wt %
	Depth			ure	.002	-.05	-2	.0002	.002	-.02	-.05	-.10	-.25	-.50	-1	-2	-5	-20	-75	75	whole
Layer	(cm)	Horz	Prep		(- % of <2mm Mineral Soil -)												(- - - - - - - % of <75mm - - - - - -)				soil
				3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3B1	3B1	3B1		
98P02474	0-13	A	S	l	26.6	31.7	41.7	2.9		23.4	8.3	7.3	11.4	10.3	7.6	5.1	4	7	18	53	29
98P02475	13-28	Btn1	S	c	52.0	21.2	26.8	12.4	8.7	16.5	4.7	4.6	7.5	7.1	5.2	2.4	5	2	2	29	9
98P02476	28-43	Btn2	S	c	50.1	26.3	23.6	10.4	12.9	21.6	4.7	4.8	5.8	5.3	5.1	2.6	5	7	3	31	15
98P02477	43-61	Btkn1	S	cl	37.0	28.4	34.6	9.1	8.8	23.8	4.6	3.8	4.5	4.9	9.8	11.6	12	28	31	81	71
98P02478	61-79	Btkn2	S	l	25.1	32.3	42.6	7.2	3.5	26.8	5.5	5.6	7.9	7.7	12.0	9.4	15	17	3	59	40
98P02479	79-117	Btkn3	S	scl	21.0	26.1	52.9	7.4	1.3	20.7	5.4	3.6	7.8	11.0	15.7	14.8	25	32	20	88	78
98P02480	117-145	2Bkn	S	fsl	13.8	25.5	60.7	7.1	1.6	18.3	7.2	11.0	25.0	16.6	6.3	1.8	2	2	--	52	4
98P02481	145-203	3BCkn	S	lcos	10.4	8.7	80.9	5.7		6.9	1.8	2.7	11.7	24.2	30.3	12.0	17	30	6	90	59

Bulk Density & Moisture

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-
				(Bulk Density)		Cole	(- - - - - - - - - - - Water Content - - - - - - - - - - -)						WRD	Aggst		
				33	Oven	Whole	6	10	33	1500	1500 kPa Ratio		Whole	Stabl	(- - Ratio/Clay - -)	
	Depth			kPa	Dry	Soil	kPa	kPa	kPa	kPa	Moist	AD/OD	Soil	2-0.5mm	CEC7	1500 kPa
Layer	(cm)	Horz	Prep	(- - - g cm^{-3} - - -)			(- - - - - - - - - - - - % of < 2mm - - - - - - - - - - - -)						cm^{3} cm^{-3}	%		
										3C2a1a		3D1		3F1a1a	8D1	8D1
98P02474	0-13	A	S							11.7		1.031		48	1.03	0.44
98P02475	13-28	Btn1	S							17.8		1.054			0.61	0.34
98P02476	28-43	Btn2	S							17.2		1.041			0.58	0.34
98P02477	43-61	Btkn1	S							13.4		1.027			0.70	0.36
98P02478	61-79	Btkn2	S							10.6		1.022			1.10	0.42
98P02479	79-117	Btkn3	S							8.6		1.020			1.30	0.41
98P02480	117-145	2Bkn	S							7.2		1.014			1.73	0.52
98P02481	145-203	3BCkn	S							7.1		1.014			2.24	0.68

*** Primary Characterization Data ***

Pedon ID: S1995-TX043-023-copy (Brewster, Texas) Print Date: Jun 27 2017 9:59AM

Carbon & Extractions

Layer	Depth (cm)	Horz	Prep	-1- Total C (% of <2 mm) 6A2e	-2- Total N (% of <2 mm) 6B4a	-3- Total S	-4- Est OC	-5- OC (WB)	-6- C/N Ratio	-7- Dith-Cit Ext Fe (% of < 2mm)	-8- Dith-Cit Ext Al	-9- Dith-Cit Ext Mn	-10- Ammonium Oxalate Extraction Al+½Fe	-11- ODOE	-12- Fe	-13- Al	-14- Si	-15- Mn (mg kg^{-1})	-16- Na Pyro-Phosphate C (% of < 2mm)	-17- Fe	-18- Al	-19- Mn
98P02474	0-13	A	S	1.01	0.102		0.9															
98P02475	13-28	Btn1	S	2.42	0.115		1.0															
98P02476	28-43	Btn2	S	3.48	0.086		0.6															
98P02477	43-61	Btkn1	S	3.17	0.062		0.1															
98P02478	61-79	Btkn2	S	2.59	0.043		--															
98P02479	79-117	Btkn3	S	1.68	0.033		--															
98P02480	117-145	2Bkn	S	1.96			0.7															
98P02481	145-203	3BCkn	S	0.40			tr															

1,1,2,3,4,5,6,7 Analyzed size fraction = <2 mm

CEC & Bases

Layer	Depth (cm)	Horz	Prep	-1- NH$_4$OAC Extractable Bases Ca (cmol(+) kg^{-1}) 6N2i	-2- Mg 6O2h	-3- Na 6P2f	-4- K 6Q2f	-5- Sum Bases	-6- Acidity 6H5a	-7- Extr Al	-8- KCl Mn (mg kg^{-1})	-9- CEC8 Sum Cats (cmol(+) kg^{-1})	-10- CEC7 NH$_4$OAC 5A8b	-11- ECEC Bases +Al	-12- Al Sat (%)	-13- Base Saturation Sum 5C3	-14- Base Saturation NH$_4$OAC 5C1
98P02474	0-13	A	S	37.4*	1.7	0.7	2.6		--				27.4			100	100
98P02475	13-28	Btn1	S	63.2*	1.9	3.8	1.6						31.6			100	100
98P02476	28-43	Btn2	S	57.1*	1.7	7.3	0.9						29.1			100	100
98P02477	43-61	Btkn1	S	52.0*	1.2	11.5	0.9						26.0			100	100
98P02478	61-79	Btkn2	S	51.1*	0.8	18.1	0.7						27.5			100	100
98P02479	79-117	Btkn3	S	65.7*	0.7	18.2	0.7						27.4			100	100
98P02480	117-145	2Bkn	S	49.5*	0.4	18.0	0.5						23.9			100	100
98P02481	145-203	3BCkn	S	39.4*	0.4	15.3	0.6		--				23.3			100	100

*Extractable Ca may contain Ca from calcium carbonate or gypsum., CEC7 base saturation set to 100.

Salt

Layer	Depth (cm)	Horz	Prep	-1- Ca (mmol(+) L^{-1}) 6N1d	-2- Mg 6O1d	-3- Na 6P1d	-4- K 6Q1d	-5- CO_3 (mmol(-) L^{-1}) 6I1b	-6- HCO_3 6J1b	-7- F 6U1c	-8- Cl 6K1e	-9- PO_4	-10- Br	-11- OAC	-12- SO_4 6L1e	-13- NO_2 6W1c	-14- NO_3 6M1e	-15- H_2O (%) 8A	-16- Total Salts (%) 8D5	-17- Elec Cond (dS m^{-1}) 8A3a	-18- Elec Cond 1:2 (dS m^{-1}) 4F1a1a1	-19- Exch Na (%)	-20- SAR 5E
98P02474	0-13	A	S	8.2	0.5	1.9	0.8	--	7.3	tr	1.7				1.6	tr	0.1	35.2	tr	1.08	0.32	2	1
98P02475	13-28	Btn1	S	1.9	0.1	8.5	0.1	--	6.6	tr	1.0				0.5	tr	tr	57.4	tr	0.98	0.47	10	9
98P02476	28-43	Btn2	S	1.0	0.1	13.3	0.1	--	6.5	0.1	3.1				1.4	tr	tr	54.6	tr	1.33	0.58	23	18
98P02477	43-61	Btkn1	S	3.1	0.2	39.6	0.1	--	5.4	tr	26.5				7.5	--	0.2	50.0	0.2	4.39	1.50	37	31
98P02478	61-79	Btkn2	S	16.4	0.9	99.2	0.2	--	2.4	tr	47.9				66.1	--	0.9	45.4	0.4	10.37	3.08	49	34
98P02479	79-117	Btkn3	S	22.1	0.9	101.1	0.2	--	2.1	tr	30.4				92.7	--	0.8	42.7	0.4	10.56	5.06	51	30
98P02480	117-145	2Bkn	S	19.3	0.8	90.0	0.2	--	2.1	tr	14.2				100.3	--	--	40.6	0.3	9.93	3.42	60	28
98P02481	145-203	3BCkn	S	7.5	0.4	72.8	tr	--	3.0	tr	11.4				61.2	--	--	29.9	0.2	7.09	1.75	56	37

*** Primary Characterization Data ***

Pedon ID: S1995-TX043-023-copy (Brewster, Texas) Print Date: Jun 27 2017 9:59AM

Sampled As : Quadria Fine, mixed, superactive, thermic Ustic Natrargids

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 98P0428

pH & Carbonates				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-
				(- - - pH					- - -)	(- - Carbonate - -) As $CaCO_3$		(- - Gypsum - - -) As $CaSO_4*2H_2O$		
Layer	Depth (cm)	Horz	Prep	KCl	$CaCl_2$ 0.01M 1:2	H_2O 1:1	Sat Paste	Oxid	NaF	<2mm	<20mm	<2mm	<20mm	Resist ohms cm^{-1}
										(- - - %			- - -)	
					4C1a2a	4C1a2a	8C1b			4E1a1a1a1	6E4b	4E2a1a1a1		
98P02474	0-13	A	S		7.9	8.5	8.3			1				
98P02475	13-28	Btn1	S		7.9	8.5	8.1			12				
98P02476	28-43	Btn2	S		8.1	8.9	8.3			24		--		
98P02477	43-61	Btkn1	S		8.2	8.7	8.1			26		--		
98P02478	61-79	Btkn2	S		8.2	8.5	8.3			22		--		
98P02479	79-117	Btkn3	S		7.9	8.0	8.3			17	5	tr		
98P02480	117-145	2Bkn	S		8.2	8.6	7.7			11		--		
98P02481	145-203	3BCkn	S		8.3	8.8	7.9			3		--		

Clay Mineralogy (<.002 mm)				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-
						X-Ray				Thermal						Elemental				EGME	Inter
													SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Na_2O	Retn	preta
	Depth		Fract			7A2i															tion
Layer	(cm)	Horz	ion	(- - - peak size				- - -)	(- - - %			- - -)	(- - - %						- - -)	mg g^{-1}	
98P02476	28.0-43.0	Btn2	tcly	CA 3	MT 1	QZ 1															
98P02478	61.0-79.0	Btkn2	tcly	MT 3	MI 2	QZ 2	CA 2	ZE 2													
				FD 1																	
98P02480	117.0-145.0	2Bkn	tcly	MT 3	MI 2	ZE 2	QZ 2	CA 2													
				FD 1																	

FRACTION INTERPRETATION:

tcly - Total Clay <0.002 mm

MINERAL INTERPRETATION:

CA Calcite FD Feldspar MI Mica MT Montmorillonite QZ Quartz

ZE Zeolite

RELATIVE PEAK SIZE: 5 Very Large 4 Large 3 Medium 2 Small 1 Very Small 6 No Peaks

*** Primary Characterization Data ***

Pedon ID: S1995-TX043-023-copy (Brewster, Texas) Print Date: Jun 27 2017 9:59AM

Sampled As : Quadria Fine, mixed, superactive, thermic Ustic Natrargids

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 98P0428

Sand - Silt Mineralogy (2.0-0.002 mm)				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-
						X-Ray					Thermal					Optical				EGME	Inter
													Tot Re			Grain Count				Retn	preta
	Depth		Fract													7B1a2					tion
Layer	(cm)	Horz	ion	(- - - - - - - - peak size - - - - - - - - -)					(- - - - - - - - % - - - - - - - - - -)				(- - - - - - - - - - - - - - - - - - - % - - - - - - - - - - - - - - - - - -)							mg g^{-1}	
98P02476	28.0-43.0	Btn2	fs										25	FK 32	AR 25	QZ 18	FP 13	ZE 4	FE 3		
														CD 3	OP 1	CB 1	CA 1	PR tr	GN tr		
														ZR tr							
98P02478	61.0-79.0	Btkn2	fs										25	AR 29	FK 20	QZ 17	ZE 12	FP 11	FE 4		
														CD 4	PR 1	CA tr	OP tr	CB tr			
98P02480	117.0-145.0	2Bkn	fs										23	AR 36	FK 21	QZ 16	FP 10	ZE 10	FE 5		
														CA 1	OP 1	CD 1	PR tr	TM tr			

FRACTION INTERPRETATION:

fs - Fine Sand 0.1-0.25 mm

MINERAL INTERPRETATION:

AR Weatherable Aggregates	CA Calcite	CB Carbonate Aggregates	CD Chert (Chalcedony	FE Iron Oxides (Goethite
FK Potassium Feldspar	FP Plagioclase Feldspar	GN Garnet	OP Opaques	PR Pyroxene
QZ Quartz	TM Tourmaline	ZE Zeolite	ZR Zircon	

Quadria: Fine, mixed, superactive, thermic Ustic Natrargids

The slope gradients for the Quadria component range from 0 to 3 percent. This component is found on broad pediment surfaces. A pediment is a gently sloping erosional surface that has been formed from the action of running water in arid and semiarid environments. This component formed in clayey alluvium which was derived primarily from tuffaceous materials of Duff and Pruett Formations and Mitchell Mesa ignimbrite. Surface fragments are sparse, and consist mainly of ignimbrite gravel and cobbles. Vegetation is mainly creosotebush, mariola, tobosa grass, and Spanish dagger (Figure 35).

Munsell color in the A horizon (0 to 13 centimeters [0 to 5.1 inches]) meets the requirements of a mollic epipedon, however, organic carbon content, minimum thickness, and days moist do not meet the requirements for a mollic epipedon. This leads to the classification of an ochric epipedon.

An abrupt textural change occurs at 13 centimeters (5.1 inches) between the A and Btn1 horizons. Clay content increases from 26.6 percent in the A horizon to 52.0 percent in the Btn1 horizon. This abrupt textural change affects the macroporosity of this pedon, and effectively creates an aquitard which restricts the downward movement of water.

An argillic horizon is recognized from 13 to 117 centimeters (5.1 to 46.1 inches), because the horizon meets the thickness and evidence of clay illuviation requirements of an argillic horizon. Lab data indicate that this soil has sodic properties, with an exchangeable sodium percentage (ESP) of 15 percent or more and a sodium adsorption ration (SAR) of 13 or more in horizons within 40 centimeters (15.7 inches) of the upper boundary of the natric horizon. A natric horizon is found from 13 to 117 centimeters (5.1 to 46.1 inches), based on the aforementioned sodic properties, in addition to meeting the thickness, evidence of clay illuviation and prismatic structure are requirements of a natric horizon.

A calcic horizon is also recognized from 43 to 145 centimeters (16.9 to 57.1 inches). Lab data show that at these depths, this pedon has 15 percent or more $CaCO_3$ equivalent and 5 percent or more $CaCO_3$ equivalent higher than an underlying horizon.

Presence of common roots occurs to a depth of 79 centimeters (31.1 inches). Below a depth of 79 centimeters (31.1 inches), the occurrence of roots decreases to few. This difference in root density may be due to a change in soil horizon textures from clays, loams, and clay loams, to sandy clay loam and fine sandy loam. The clays, loams, and clay loams are able to store more water, which may allow plants to expand their root system. The zeolitic mineralogy of this component also increases the available water capacity, thereby increasing the plant available water in the soil.

This pedon was originally classified as Calcic Paleargids, but was reclassified using lab data to Ustic Natrargids due to the evidence of a natric horizon mentioned previously. The particle-size control section is from 13 to 63 centimeters (5.1 to 24.8 inches). The CEC activity class is superactive, based on a CEC to clay ratio of 0.84.

Figure 35. Pediment landscape showing Quadria forming in clayey alluvium. Creosotebush and Spanish dagger are visible.

A Knowledge-Based Approach to SSURGO Disaggregation in Order 3 Soil Survey: Green Valley, Trans-Pecos Texas

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USDA-Natural Resources Conservation Service
Marfa Soil Survey Office

Abstract

Using traditional mapping techniques, scientists working with the National Cooperative Soil Survey have provided high quality resource maps to land managers for more than a century. In recent times these maps and associated data (SSURGO) in Trans-Pecos Texas were compiled at a scale of 1:31,680 or 1:24,000. Attribute data has traditionally been generalized, wherein multiple, similar soil taxonomic units have been aggregated as a single soil component. In many instances SSURGO serves the users well; however, in others, the soil components do not adequately reflect important hydrologic and ecological processes at a scale relevant to decision-makers. An example is the Quadria soil (fine, mixed, superactive, thermic, Ustic Natrargids) forming on a broad, nearly level pediment surface in which the presence or absence of a gravel veneer (~70 percent surface fragments) has important hydrologic and ecological consequences, but little impact on soil physical, chemical, and morphological properties.

In this approach to disaggregation, we portray with greater detail the more productive ecological site-soil components, which offer greater hydrologic and ecological services. This value-added method requires an understanding of landscape evolution, pedogenic processes, and their interrelationship to the important drivers of range ecology. Several steps are utilized in this knowledge-based process, beginning with the current SSURGO product. Following a preliminary compilation of ecological site-soil components and the assemblage and creation of relevant environmental covariates, field visits develop an understanding of relationships among components and covariates. Next, the list of components and covariates is refined for the purpose of directing sampling efforts to these components. Directed, constrained, conditioned Latin hypercube sampling is employed to describe the significant components within time constraints. We use ArcSIE software to model components by drafting rules that describe their distribution with respect to covariates; the resulting rulebase archives our present knowledge of those relationships. This process is not linear in the sense that a task is performed only once, never to be revisited. Rather this knowledge-based approach to soil modeling is an iterative process through which the ecological site-soil components, environmental covariates, their interrelationships, and the raster portrayal of component spatial distribution are continually honed and refined. Our recorded conceptual model will serve as the basis for future soil survey updates.

When completed, this project will provide a value-added soil survey across the 160,000 hectares (395,368.61 acres) extent of the newly developed Green Valley Land Resource Unit (LRU), a subdivision of the Southern Desertic Basins, Plains, and Mountains (MLRA 42). Newly defined ecological sites will be linked to the unique suite of zeolitic soils that occur within the Green Valley LRU. The detailed raster maps will inform decision-making for grazing land managers and wildlife managers as the spatial distribution of high value areas are displayed.

Introduction

One objective of the Green Valley SSURGO disaggregation project is to redefine the Quadria, Beewon, and Musgrave soils, 0 to 30 percent slopes map unit (QBE). This undifferentiated map unit does not portray the spatial distribution of the three contrasting ecological sites. Spatial portrayal of the components is needed to meet current user needs. Though the project encompasses all of Green Valley (Figure 36), this presentation will focus on QBE and adjacent map units.

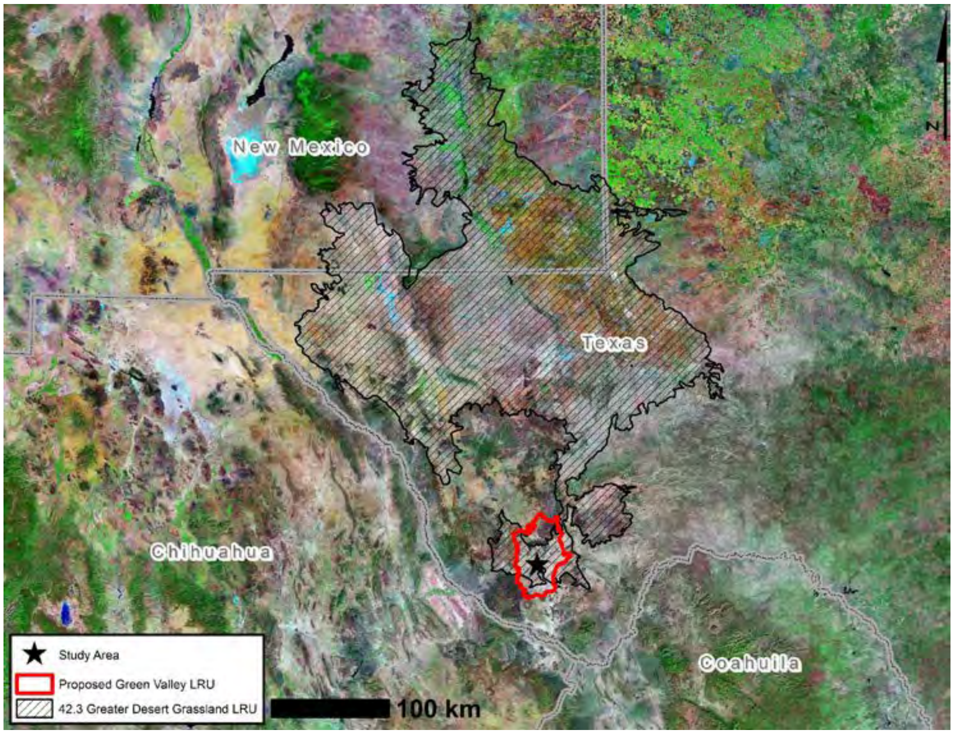

Figure 36. Map of the Trans-Pecos region.

The proposed Green Valley LRU is dominated by soils (Figure 37, Table 3) forming in zeolitic parent materials (residuum, pedisediment, and stream alluvium) derived from tuffaceous bedrock of the Duff, Pruett, and Devils Graveyard Formations (Goldich and Elms, 1949; Stevens et al., 1984). These zeolitic soils have CEC/clay ratios greater than 1.00. Consequently, they possess available water capacity that is higher than similar soils that formed in parent materials with non-zeolitic mineralogy.

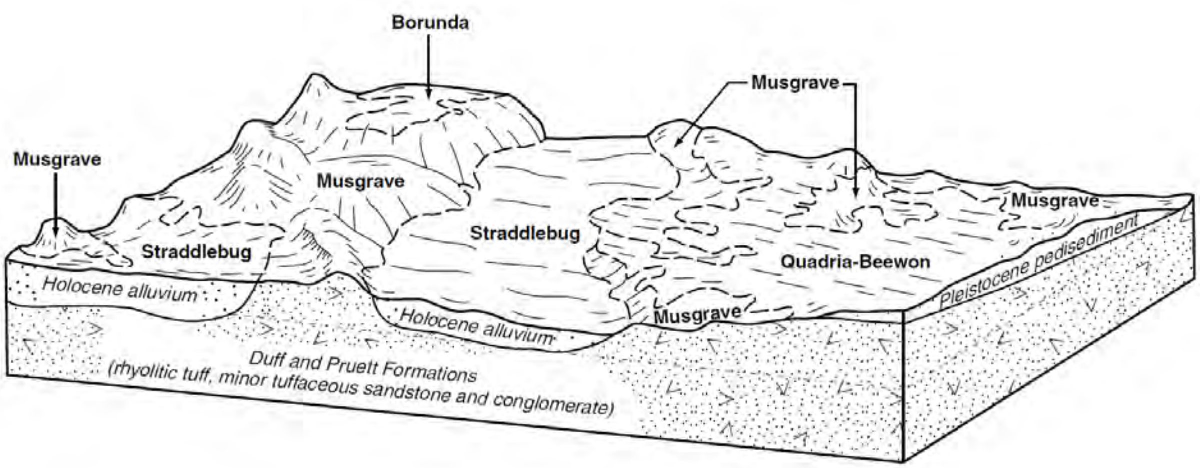

Figure 37. Block diagram illustrating geomorphic relationships of dominant soils.

Table 3. Classification, CEC/clay ratio, dominant landform, and estimated geomorphic surface age of soils in Green Valley.

Soil Name	Family or Higher Taxonomic Class	CEC / Clay Ratio	Landform	Geomorphic SurfaceAge
Beewon	Loamy-skeletal, mixed, superactive, thermic Ustic Calciargids	0.65	pediment	mid-Pleistocene
Borunda	Fine, mixed, superactive, thermic Ustic Calcigypsids	1.46	erosional remnant	late-Pleistocene
Musgrave	Clayey, mixed, superactive, calcareous, hyperthermic, shallow Ustic Torriorthents	1.42	erosional remnant	late-Holocene
Nillo	Fine-silty, mixed, superactive, calcareous, thermic Ustic Torrifluvents	0.88	flood plain	late-Holocene
Quadria	Fine, mixed, superactive, thermic Ustic Natrargids	1.21	pediment	mid-Pleistocene
Rockpens	Loamy-skeletal, mixed, superactive, thermic Sodic Ustic Haplocambids	1.56	Strath terrace	late-Pleistocene
Straddlebug	Fine-loamy, mixed, superactive, thermic Sodic Ustic Haplocambids	0.93	stream terrace	Early-Holocene

Rangeland is the dominant land use in Trans Pecos Texas, and ecological sites are the predominant interpretation derived from soil survey. Therefore, we elevate ecological site to a level at or above soil in this modeling effort. An ecological site is a conceptual division of the landscape. It is defined as “a distinctive kind of land based on recurring soil, landform, geological, and climate characteristics that differs from other kinds of land in its ability to produce distinctive kinds and amounts of vegetation and in its ability to respond similarly to management actions and natural disturbances.”

The Desert Grassland Loamy and Gravelly ecological sites linked to the Quadria and Beewon components, respectively, represent very broadly defined concepts; they encompass a region extending from central Brewster County, Texas, northward along the Pecos River to Roswell, New Mexico (Figure 36). Consequently, statements in the ecological site descriptions, including values of rangeland production, may not be finely tuned to the specific conditions of a particular ranch. In contrast, the Clay Hill ecological site linked to the Musgrave soil was specifically designed for clayey soils, shallow to tuffaceous mudstone bedrock, within the Hot Desert Shrub ecological zone.

Methods

The Marfa SSO staff performed these field investigations and related GIS tasks:

1) From SSURGO spatial and tabular data: a) identify homogenous areas (Van Zijl et al., 2014) and b) develop a legend of ecological site-soil components to be modeled.

2) Assemble relevant DEM and image data, create numerous DEM- and image-derived environmental covariates, and then identify covariates that can potentially define the spatial distribution of the components.

3) Perform directed, constrained, conditioned Latin hypercube sample (cLHS) allocation implementing the methods outlined in (Minasny and McBratney, 2006) and (Roudier et al., 2012).

4) Describe site-vegplot-pedon triplets (Figure 38) at cLHS and additional purposive points using the methods outlined in (Schoeneberger et al., 2012).

5) Discover relationships between components and the covariates that control their distribution.

6) Draft rules within ArcSIE (Shi et al., 2009) that archive our understanding of the component-covariate relationships.

7) Execute rules to create raster maps of fuzzy membership for each component within the project area.

8) Harden the individual fuzzy component rasters to create a raster of the dominant component within each pixel (Figure 39).

9) Collect vegetation production data (Figure 38) for representative plots of using the methods outlined in (Herrick et al., 2009).

10) Create using ArcSIE, a weighted average fuzzy ecological site property maps, including vegetation productivity.

These sequential milestones compose the raster mapping process. However, the process is not linear in the sense that a task is performed only once, never to be revisited. Rather, raster mapping is an iterative process through which the ecological site-soil components, environmental covariates, their interrelationships, and the portrayal of component spatial distribution by raster are continually honed and refined. We had to incorporate new components into our thinking; new environmental covariates were required to model them in ArcSIE.

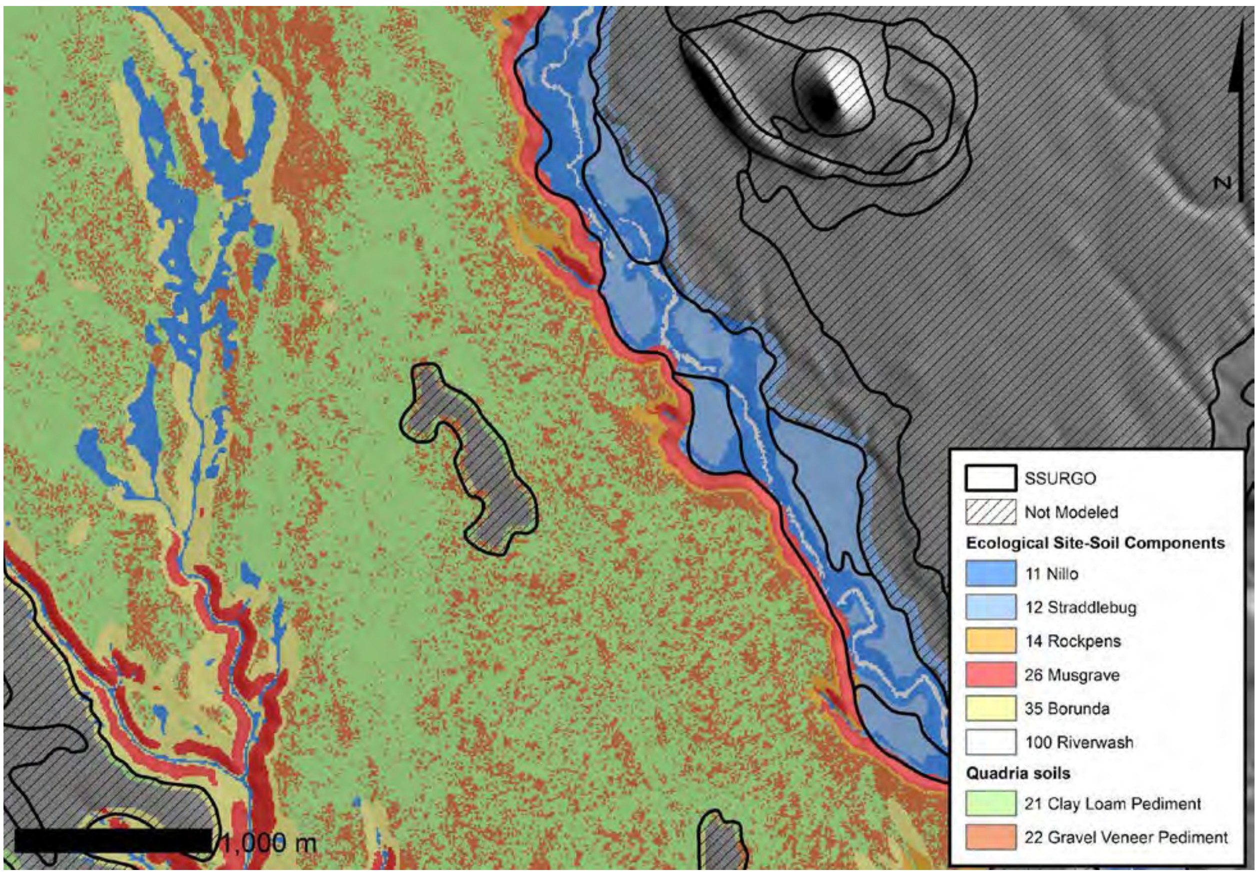

Figure 39. Hardened component map of the mid-Pleistocene pediment and adjacent landforms.

Discussion of Methods

The published soil survey manuscript provides an initial legend of components to be modeled. To refine the legend requires knowledge of 1) current and future user information needs; and 2) significant ecological and soil processes. Homogenous areas are defined by grouping SSURGO map units with respect to the dominant parent material, relief, and time (Table 4). By sampling and modeling within homogeneous areas, the limited number of sample points are allocated to locations that have meaning to the range ecologist and soil scientist. For example, distinct landforms represented by four homogeneous areas (Table 5) have similar values of slope gradient (Figure 40).

Table 4. Genetic factors driving vegetation and soil development within the QBE map unit.

Factor	**Description**
Relief/Time	Nearly level Quaternary-age pediments dissected by Holocene age drainageways
Parent Material	Clayey pedisediment and tuffaceous mudstone with a discontinuous gravel veneer
Climate	MAAT: 18 C; MAP: 325 mm; AWD: 650 mm
Organisms	Chihuahuan Desert plants adapted by drought avoidance/tolerance to water stress

Table 5. SSURGO map units and homogenous areas adjacent to the QBE map unit.

Map Unit Symbol	**Map Unit Name**	**Map Unit Kind**	**Homogenous Area**	**Dominant Landform**
BOC	Borunda soils, 1 to 8 percent slopes	Undifferentiated group	2	erosional remnant
MUD	Musgrave-Rockpens association, 1 to 8 percent slopes	Association	3	strath terrace/erosional remnant
NLA	Nillo silty clay, 0 to 3 percent slopes, occasionally flooded	Consociation	4	flood plain
QBE	Quadria, Beewon and Musgrave soils, 0 to 30 percent slopes	Undifferentiated group	1	pediment/erosional remnant
SRA	Straddlebug clay loam, 0 to 3 percent slopes	Consociation	4	stream terrace

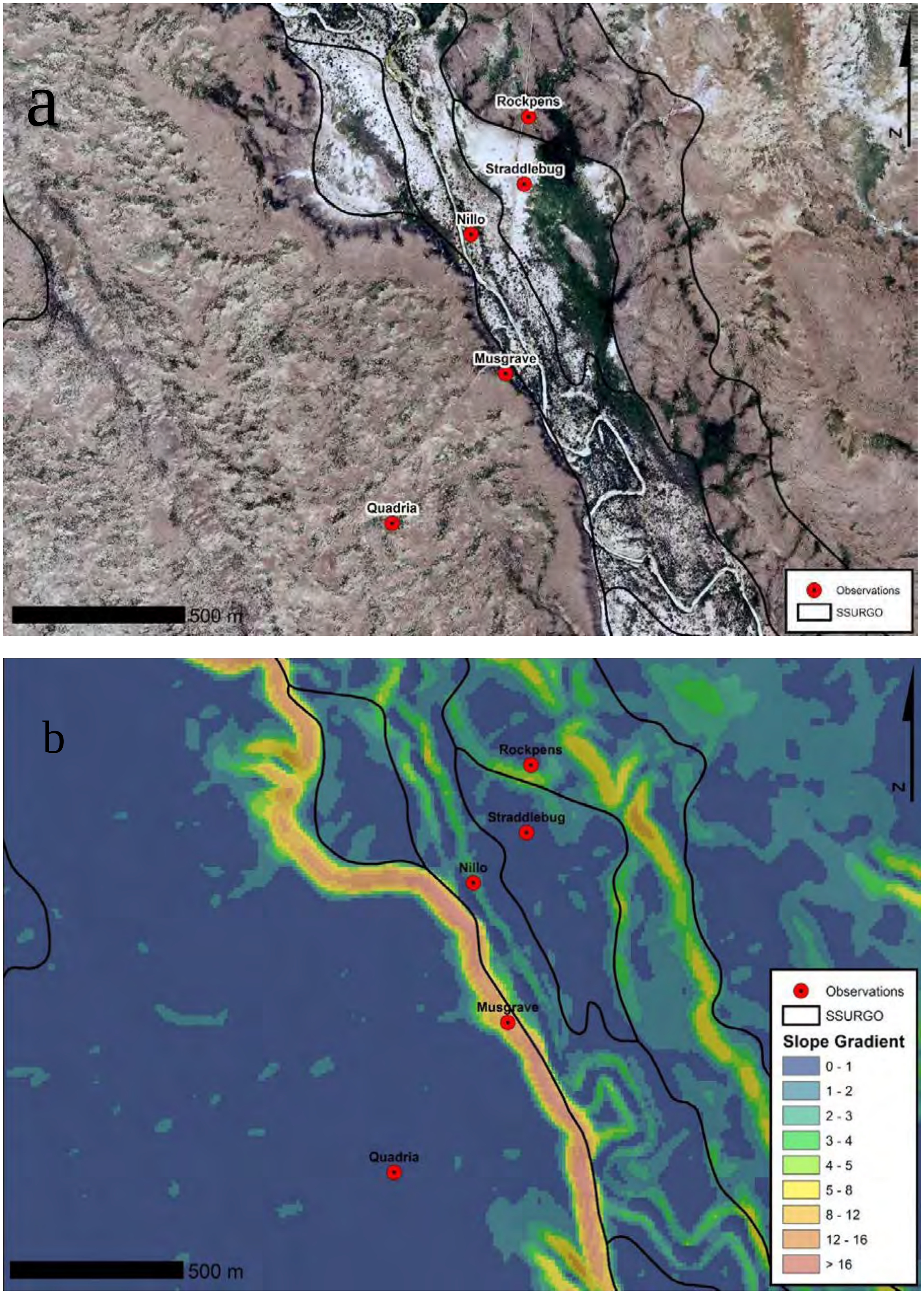

Figure 40. SSURGO map of mid-Pleistocene pediment and adjacent landforms on: (a) NAIP and (b) slope gradient.

At the outset of this project, many environmental covariates were created through several iterations until the current environmental covariate database was formulated. Covariates currently utilized within the QBE map unit are listed in Table 6. We implemented cLHS within the R software environment (Minasny and McBratney, 2006; Roudier et al. 2012).

Table 6. Environmental covariates used to model components within the QBE map unit.

Name	Description	Software	Reference
height above stream	Average vertical drop to stream	TauDEM	Tesfa et al., 2009
wetness index	D-Inf contributing area and slope	TauDEM	Tarboton, 1997
IFSAR digital terrain model	Focal mean smoothing (3 cell neighborhood) of 10m data aggregated from 5m	ESRI	
ridgetop flatness index	Flatness is measured by the inverse of slope and lowness is measured by a ranking of elevation with respect to a circular neighborhood	SAGA	Gallant and Dowling, 2003
normalized difference vegetation index	NDVI calculated from NAIP imagery (10/2014)	ERDAS	
slope gradient	Calculated using the D-Infinity method	TauDEM	Tarboton, 1997
standardized slope height	Calculates standardized elevation with respect to relative position (high/low) multiple iterations eliminate the effects of watersheds	SAGA	Böhner and Selige, 2006

Two critical tasks in the process are: 1) to identify a covariate that can distinguish conceptually and spatially adjacent components; and 2) then find the threshold value that separates them. This benefits from purposive sample points in addition to the cLHS allocated points.

ArcSIE provides a method to model components and archive knowledge of component-covariate relationships. Rules are implemented in the ArcSIE Inference Engine (Figure 41a). Current understanding of the relationship of two components (Quadria and Musgrave) with respect to slope gradient is illustrated in Figure 41b. Implementation of the rules for Musgrave is illustrated by the fuzzy membership raster in Figure 42.

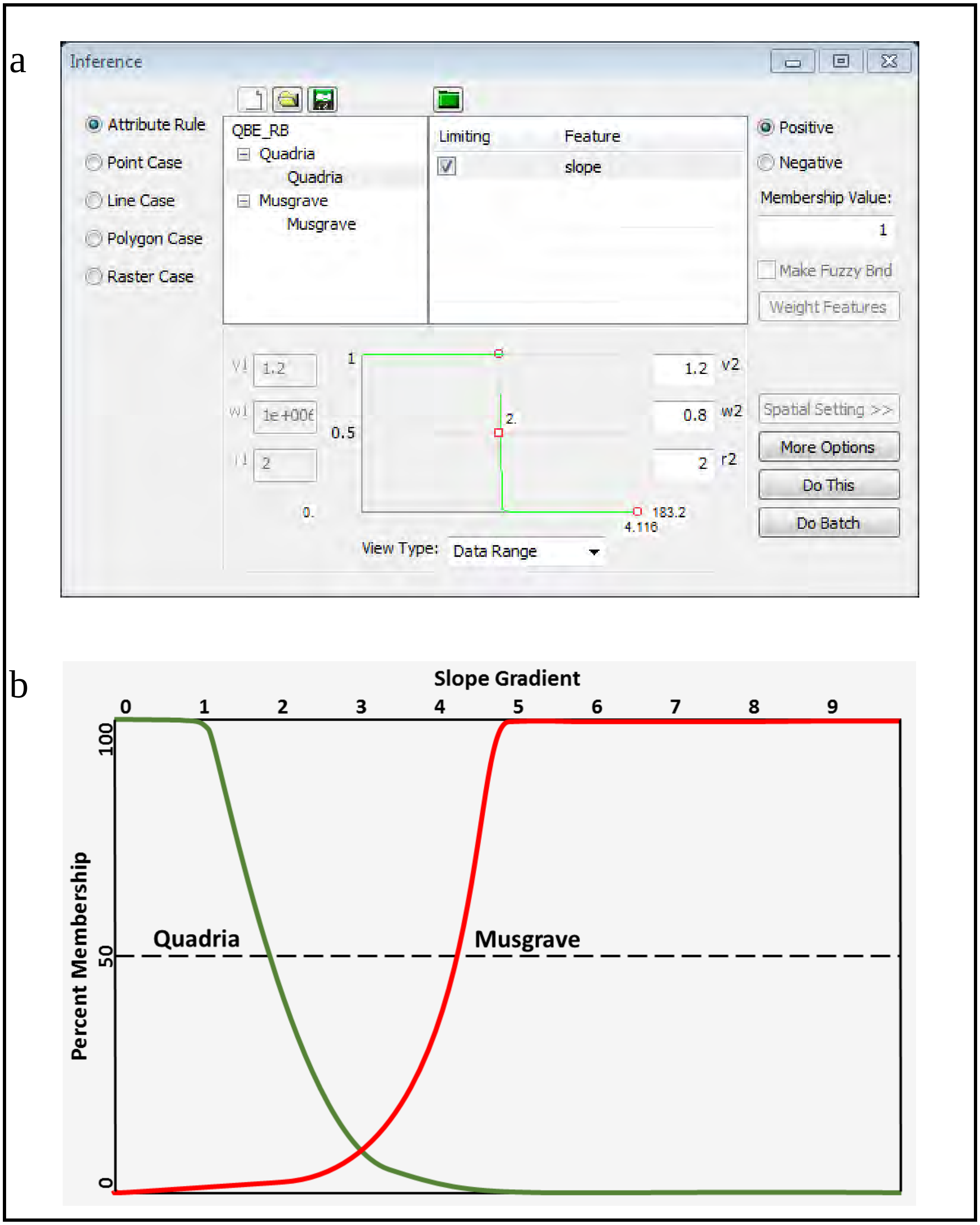

Figure 41. (a) ArcSIE Inference Engine dialog box; and (b) fuzzy membership functions of Quadria and Musgrave components with respect to slope gradient.

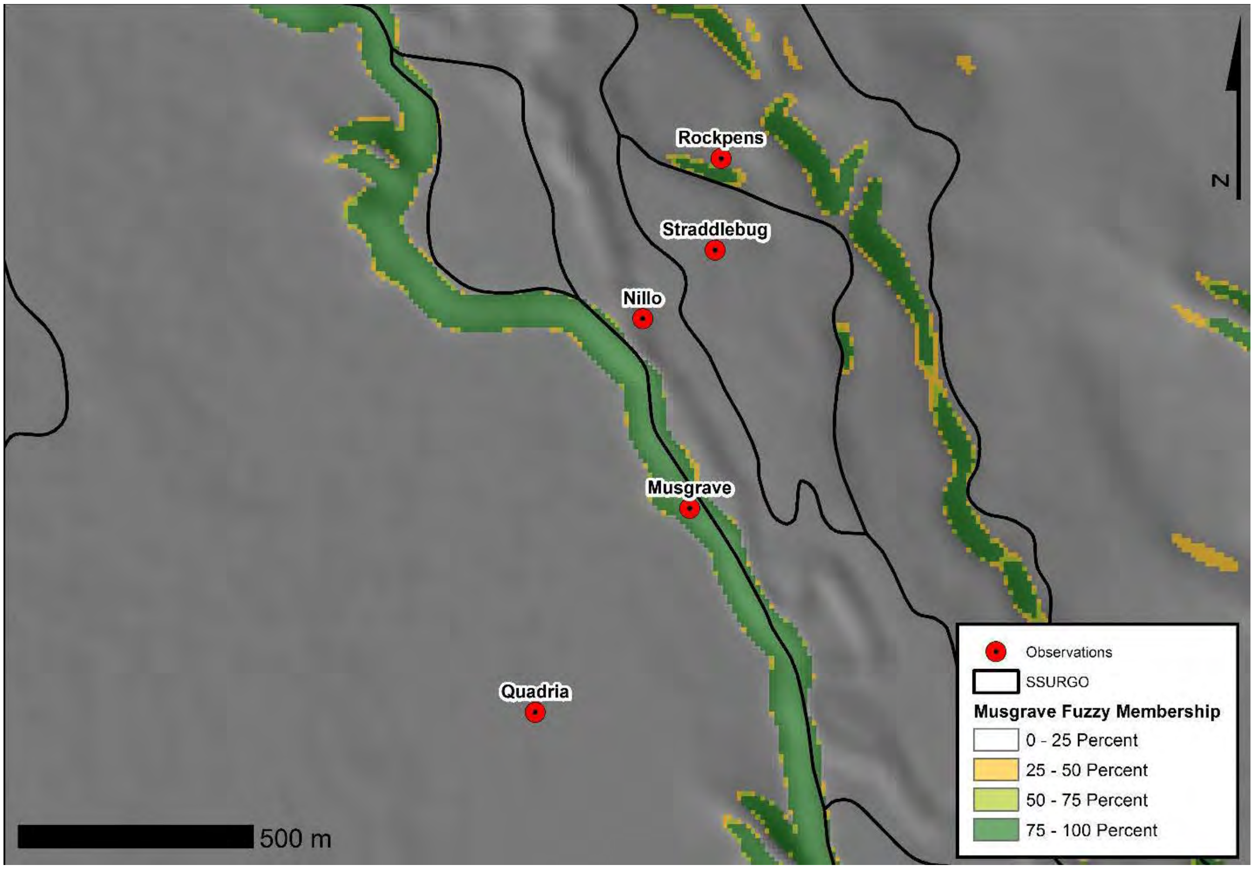

Figure 42. Fuzzy membership of the Musgrave component draped over shaded relief image.

Conclusion

Raster methods allow portrayal of small areas with high productivity within a broader area with low production, and areas too small for delineation on polygon soil maps. As a result, better accounting of forage production, more accurate estimates of carrying capacity and recommended stocking rates are possible. Areas with high value wildlife habitat and flood hazard along drainageways too narrow for inclusion on normal polygon soil surveys can be depicted. Raster maps can show how much and specifically where resources of varying value exist.

We recommend that SSURGO tables linked to raster map units provide component level data such as rangeland productivity.

Figure. 43. Marfa SSO Staff describing site-vegplot-pedon triplets and collecting vegetation production data.

Stop 5 – Musgrave Soil

Clay Hill Ecological Site

Print Date: Jun 29 2017

Description Date: Jan 1 1996

Describer: Lynn Loomis and Jerry Rives

Site ID: S1996-TX043-001-copy

Pedon ID: S1996-TX043-001-copy

Lab Source ID: SSL

Lab Pedon #: 98P0427

Soil Name: Musgrave

Classification: Clayey, mixed, superactive, calcareous, hyperthermic, shallow Typic Torriorthents

Particle-Size Control Section: 25 to 46 cm.

Diagnostic Features: ochric epipedon 0 to 13 cm.
densic materials 46 to 200 cm.
densic contact 46 to 46 cm.

Country: United States

State: Texas

County: Brewster

MLRA: Southern Desertic Basins, Plains, and Mountains

Soil Survey Area: Brewster County, Texas (Main Part)

Quad Name: Straddlebug Mountain, Texas

Std Latitude: 29.7644444

Std Longitude: -103.7080536

Latitude: 29 deg 45 min 52 sec north

Longitude: 103 deg 42 min 29 sec west

Datum: WGS84

UTM Zone: 13

UTM Easting: 624920 meters

UTM Northing: 3293392 meters

Existing Vegetation: Arizona cottontop, bush muhly, Chino grama, creosote bush, false grama, littleleaf ratany, ocotillo, plains bristlegrass, sideoats grama, slim tridens, whitethorn acacia

Parent Material: zeolitic and sodic loamy residuum weathered from tuff

Bedrock Kind: Tuff

Bedrock Depth: 46 centimeters

Bedrock Hardness: noncemented

Bedrock Fracture Interval:

Surface Fragments: 20 percent Ignimbrite gravel and 10 percent Ignimbrite cobbles and 5 percent Ignimbrite stones

Top Depth (cm)	Bottom Depth (cm)	Restriction Kind	Restriction Hardness
46	200	bedrock, densic	Noncemented

Slope (%)	Elevation (meters)	Aspect (deg)	MAAT (C)	MSAT (C)	MWAT (C)	MAP (mm)	Frost-Free Days	Drainage Class	Slope Length (meters)	Upslope Length (meters)
14.7	1,097.4		18.4			323		well		

Musgrave

A--0 to 13 centimeters (0.0 to 5.1 inches); light brownish gray (10YR 6/2) silty clay loam, grayish brown (10YR 5/2), moist; moderate fine and medium subangular blocky structure; hard, firm; sticky and plastic; common very fine and fine roots; violent effervescence; moderately alkaline, clear smooth boundary. Lab sample # 98P02471.

Ck--13 to 46 centimeters (5.1 to 18.1 inches); grayish brown (10YR 5/2) silty clay loam, grayish brown (10YR 5/2), moist; hard, firm; noneffervescent; moderately alkaline, pH 8.2, Hellige-Truog; clear smooth boundary. Lab sample # 98P02472. Rock structure; sticky and plastic; 75 percent unweathered tuff fragments that slake in water; common coarse irregular white (10YR 8/1) masses of calcium carbonate in cracks.

Cdk--46 to 71 centimeters (18.1 to 28.0 inches); light brownish gray (2.5Y 6/2) weathered tuff bedrock, grayish brown (2.5Y 5/2), moist; non-cemented; 1 percent prominent iron stains throughout; 3 percent coarse irregular white (10YR 8/1) carbonate masses in cracks; noneffervescent; moderately alkaline, Lab sample # 98P02473.

*** Primary Characterization Data ***

Pedon ID: S1996-TX043-001-copy | (Brewster, Texas) | Print Date: Jun 27 2017 10:16AM

Sampled as on Dec 30, 1995: MUSGRAVE
Revised to correlated on Apr 6, 2016: Musgrave ; Clayey, mixed, superactive, calcareous, hyperthermic, shallow Typic Torriorthents

SSL - Project CP98TX119 BREWSTER COUNTY
- Site ID S1996-TX043-001-copy Lat: 29° 45' 52.00" north Long: 103° 42' 28.99" west MLRA: 42
- Pedon No. 98P0427
- General Methods 1B1A, 2A1, 2B

United States Department of Agriculture
Natural Resources Conservation Service
National Soil Survey Center
Soil Survey Laboratory
Lincoln, Nebraska 68508-3866

Layer	Horizon	Orig Hzn	Depth (cm)	Field Label 1	Field Label 2	Field Label 3	Field Texture	Lab Texture
98P02471	A	A	0-13				SICL	CL
98P02472	Ck	Ck	13-46				SICL	CL
98P02473	Cdk	Crk	46-71					SICL

PSDA & Rock Fragments

Layer	Depth (cm)	Horz	Prep	-1- Lab Texture	-2- Total Clay < .002	-3- Total Silt .002 -.05	-4- Total Sand .05 -2	-5- Clay Fine < .0002	-6- Clay CO_3 < .002	-7- Silt Fine .002 -.02	-8- Silt Coarse .02 -.05	-9- Sand VF .05 -.10	-10- Sand F .10 -.25	-11- Sand M .25 -.50	-12- Sand C .5 -1	-13- Sand VC 1 -2	-14- Rock Fragments (mm) Weight 2 -5	-15- Weight 5 -20	-16- Weight 20 -75	-17- Weight .1- 75	-18- >2 mm wt % whole soil
					(- % of <2mm Mineral Soil											- -)	(- - - - - - - % of <75mm			- - - - - -)	
				3A1a1a	3A1a1a	3A1a1a	3A1a1a		3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3B1	3B1	3B1		
98P02471	0-13	A	S	cl	39.5	39.7	20.8		0.8	32.5	7.2	7.1	11.1	1.9	0.4	0.3	1	tr	--	15	1
98P02472	13-46	Ck	S	cl	35.2	43.6	21.2			36.3	7.3	6.0	10.1	4.8	0.2	0.1	28	8	--	46	36
98P02473	46-71	Cdk	S	sicl	29.6	50.4	20.0			46.2	4.2	5.3	10.3	4.1	0.3	tr	25	22	--	55	47

Bulk Density & Moisture

Layer	Depth (cm)	Horz	Prep	-1- (Bulk Density) 33 kPa	-2- Oven Dry	-3- Cole Whole Soil	-4- Water Content 6 kPa	-5- 10 kPa	-6- 33 kPa	-7- 1500 kPa	-8- 1500 kPa Moist	-9- Ratio AD/OD	-10- WRD Whole Soil	-11- Aggst Stabl 2-0.5mm	-12- (- - Ratio/Clay - -) CEC7	-13- 1500 kPa
				(- - - g cm^{-3} - - -)			(- - - - - - - - - - - - % of < 2mm				- - - - - - - - - - - -)		cm^3 cm^{-3}	%		
										3C2a1a		3D1		3F1a1a	8D1	8D1
98P02471	0-13	A	S							20.1		1.066		35	1.39	0.51
98P02472	13-46	Ck	S							21.5		1.070			1.54	0.61
98P02473	46-71	Cdk	S							17.4		1.071			1.56	0.59

Carbon & Extractions

Layer	Depth (cm)	Horz	Prep	-1- (- - - - - Total C	-2- N	-3- S - - - - -)	-4- Est OC	-5- OC (WB)	-6- C/N Ratio	-7- (- - - Dith-Cit Ext Fe	-8- Al	-9- Mn - - -)	-10- (- - - - - - Ammonium Oxalate Extraction Al+½Fe	-11- ODOE	-12- Fe	-13- Al	-14- Si	-15- Mn - - - - - -)	-16- (- - - Na Pyro-Phosphate C	-17- Fe	-18- Al	-19- Mn - - -)
				(- - - - - - - - - - % of <2 mm					- - - - - - - - - -)	(- - - - - - - - - - - - - - - - - - - % of < 2mm								- - - - - - - - - - - - - - - - -)	mg kg^{-1}	(- - - - - - % of < 2mm			- - - - -)
				6A2e	6B4a																	
98P02471	0-13	A	S	0.78	0.052		0.3															
98P02472	13-46	Ck	S	0.97	0.036		0.3															
98P02473	46-71	Cdk	S	1.99			--															

[1,1,2] Analyzed size fraction = <2 mm

*** Primary Characterization Data ***

Pedon ID: S1996-TX043-001-copy (Brewster, Texas) Print Date: Jun 27 2017 10:16AM
Sampled As : MUSGRAVE
USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 98P0427

CEC & Bases				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-
				(- - - - - - NH_4OAC Extractable Bases - - - - -)								CEC8	CEC7	ECEC		(- - - - Base - - - -)	
								Sum	Acid-	Extr	KCl	Sum	NH_4	Bases	Al	(- Saturation -)	
	Depth			Ca	Mg	Na	K	Bases	ity	Al	Mn	Cats	OAC	+Al	Sat	Sum	NH_4OAC
Layer	(cm)	Horz	Prep	(- - - - - - - - - - - - - - - - - - cmol(+) kg^{-1} - - - - - - - - - - - - - - - - - - -)							mg kg^{-1}	(- - - - cmol(+) kg^{-1} - - -)			(- - - - - - - - % - - - - - - - -)		
				6N2i	6O2h	6P2f	6Q2f						5A8b			5C3	5C1
98P02471	0-13	A	S	80.2*	1.5	7.7	0.9						54.8			100	100
98P02472	13-46	Ck	S	73.4*	1.4	11.8	0.7						54.3			100	100
98P02473	46-71	Cdk	S	66.9*	1.4	11.8	0.6						46.2			100	100

*Extractable Ca may contain Ca from calcium carbonate or gypsum. CEC7 base saturation set to 100.

Salt				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-	-19-	-20-
				(- Water Extracted From Saturated Paste -)																	1:2		
																			Total	Elec	Elec	Exch	
	Depth			Ca	Mg	Na	K	CO_3	HCO_3	F	Cl	PO_4	Br	OAC	SO_4	NO_2	NO_3	H_2O	Salts	Cond	Cond	Na	SAR
Layer	(cm)	Horz	Prep	(- - - - - mmol(+) L^{-1} - - - - -)				(- mmol(-) L^{-1} -)										(- - - - % - - - -)		(- - dS m^{-1} - -)		%	
				6N1d	6O1d	6P1d	6Q1d	6I1b	6J1b	6U1c	6K1e				6L1e	6W1c	6M1e	8A	8D5	8A3a	4F1a1a1		5E
98P02471	0-13	A	S	1.3	tr	11.0	tr	--	7.3	0.1	0.7				1.3	1.2	0.3	49.9	tr	1.16	0.50	13	14
98P02472	13-46	Ck	S	1.2	tr	14.8	0.1	--	6.9	0.5	2.0				2.2	1.0	2.6	48.9	tr	1.52	0.49	20	19
98P02473	46-71	Cdk	S	1.6	0.1	17.8	0.1	--	5.4	0.8	2.8				6.0	0.4	1.2	43.7	0.1	1.83	0.65	24	19

pH & Carbonates				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-
				(- - - - - - - - - - - - - - - - - - pH - - - - - - - - - - - - - - - - - -)						(- - Carbonate - -)		(- - Gypsum - - -)		
					$CaCl_2$					As $CaCO_3$		As $CaSO_4{*}2H_2O$		Resist
	Depth				0.01M	H_2O	Sat			<2mm	<20mm	<2mm	<20mm	ohms
Layer	(cm)	Horz	Prep	KCl	1:2	1:1	Paste	Oxid	NaF	(- - - - - - - - - - - - % - - - - - - - - - - - -)				cm^{-1}
					4C1a2a	4C1a2a	8C1b			4E1a1a1a1		4E2a1a1a1		
98P02471	0-13	A	S		8.1	8.9	8.2			4		--		
98P02472	13-46	Ck	S		8.4	9.1	8.3			6				
98P02473	46-71	Cdk	S		8.4	8.9	8.2			18		--		

Clay Mineralogy (<.002 mm)				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-
				X-Ray					Thermal				Elemental							EGME	Inter
													SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Na_2O	Retn	preta
	Depth		Fract	7A2i																	tion
Layer	(cm)	Horz	ion	(- - - - - - - - - peak size - - - - - - - - - -)					(- - - - - - - - - % - - - - - - - - - -)				(- % -)							mg g^{-1}	
98P02472	13.0-46.0	Ck	tcly	MT 3	QZ 2	CA 1															

FRACTION INTERPRETATION:
tcly - Total Clay <0.002 mm

MINERAL INTERPRETATION:
CA Calcite MT Montmorillonite QZ Quartz

RELATIVE PEAK SIZE: 5 Very Large 4 Large 3 Medium 2 Small 1 Very Small 6 No Peaks

Sand - Silt Mineralogy (2.0-0.002 mm)				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-
				X-Ray					Thermal				Optical							EGME	Inter
													Tot Re	Grain Count						Retn	preta
	Depth		Fract										7B1a2								tion
Layer	(cm)	Horz	ion	(- - - - - - - - peak size - - - - - - - - -)					(- - - - - - - - % - - - - - - - - - -)				(- % - - - - - - - - - - - - - - - - - - -)							mg g^{-1}	
98P02472	13.0-46.0	Ck	fs										0	AR 96	CA 2	FK 1	QZ tr	GS tr			

FRACTION INTERPRETATION:
fs - Fine Sand 0.1-0.25 mm

MINERAL INTERPRETATION:
AR Weatherable Aggregates CA Calcite FK Potassium Feldspar GS Glass QZ Quartz

Musgrave: Clayey, mixed, superactive, calcareous, hyperthermic, shallow Ustic Torriorthents

The slope gradients for Musgrave range from 1 to 30 percent. The parent material is residuum derived from weathered tuff bedrock of the Chisos, Duff, Pruett, and Devils Graveyard Formations. This component occurs on scarps and erosional remnants located on the side slopes of Pleistocene-age pediments. The components that occur on the pediment surfaces above the Musgrave scarp slopes are generally either Quadria or Beewon. Vegetation is mainly viscid acacia, creosotebush, and tobosa grass (Figure 44).

The Munsell color and the depth of the A horizon (0 to 13 centimeters [0.0 to 5.1 inches]) do not meet the requirements for a mollic epipedon, therefore the epipedon is ochric.

There is densic contact at 46 centimeters (18.1 inches), where the Cdk horizon begins. Densic materials can be found in the zone from 46 to 200 centimeters (18.1 to 78.7 inches). The Cdk horizon is weakly cemented with coarse, irregular carbonate masses in cracks. Gypsum crystals can also occur in fractures.

Common roots are described in the A horizon to a depth of 13 centimeters (5.1 inches). There are no roots described in the Ck horizon from 13 to 46 centimeters (5.1 to 18.1 inches), which may be because this horizon is extremely gravelly with a fragment volume of 75 percent tuff gravel. At 46 centimeters (18.1 inches) is a densic contact, which is root-restrictive. Residuum derived from tuff is the parent material of this soil, which contains abundant zeolite minerals that typically have CEC values of 200 to 300 cmol/kg. This zeolitic mineralogy increases the available water capacity, which increases the plant available water in the A horizon.

The particle-size control section is from 25 to 46 centimeters (9.8 to 18.1 inches). The CEC activity class is superactive, based on a CEC to clay ratio of 1.54.

Figure 44. Scarp slope landform with Musgrave forming in residuum derived from tuff bedrock. Creosotebush dominates vegetation on the overlying pediment surface.

Stop 6 – Rockpens Soil

Print Date: Jun 29 2017
Description Date: Apr 10 1995
Describer: Lynn Loomis, Jerry Rives, and Alan Terrell
Site ID: S1995-TX043-021-copy
Pedon ID: S1995-TX043-021-copy
Lab Source ID: SSL
Lab Pedon #: 98P0429
Soil Name: Rockpens
Classification: Loamy-skeletal, mixed, superactive, thermic Sodic Ustic Haplocambids

Country: United States
State: Texas
County: Brewster
MLRA: Southern Desertic Basins, Plains, and Mountains
Soil Survey Area: Brewster County, Texas (Main Part)
Quad Name: Straddlebug Mountain, Texas
Std Latitude: 29.7849998
Std Longitude: -103.7316666
Latitude: 29 deg 47 min 6 sec north
Longitude: 103 deg 43 min 54 sec west
Datum: NAD83
UTM Zone: 13
UTM Easting: 624257 meters
UTM Northing: 3295865 meters
Existing Vegetation: Arizona cottontop, black grama, blue grama, cane bluestem, creosote bush, fourwing saltbush, littleleaf ratany, sandhill muhly, sideoats grama, streambed bristlegrass
Bedrock Kind: Tuff
Bedrock Depth: 175 centimeters
Bedrock Hardness: moderately cemented

Geomorphic Setting: strath terrace on valley on piedmont
Particle-Size Control Section: 25 to 100 cm.
Diagnostic Features: ochric epipedon 0 to 8 cm.
cambic horizon 8 to 69 cm.
paralithic contact 175 to 175 cm.
paralithic materials 175 to 246 cm.

Top Depth (cm)	Bottom Depth (cm)	Restriction Kind	Restriction Hardness
175	216	bedrock, paralithic	Moderately cemented

Rockpens

A--0 to 8 centimeters (0.0 to 3.1 inches); brown (7.5YR 5/3) sandy loam, brown (7.5YR 4/3), moist; moderate medium and coarse subangular blocky parts to moderate fine and medium subangular blocky structure; slightly hard, very friable, slightly sticky, slightly plastic; common very fine and fine roots; few very fine tubular pores; 5 percent rounded ignimbrite gravel; strong effervescence; slightly alkaline; clear smooth boundary. Lab sample # 98P02482.

Bn1--8 to 36 centimeters (3.1 to 14.2 inches); brown (7.5YR 5/3) gravelly loam, brown (7.5YR 4/3), moist; moderate medium and coarse subangular blocky parts to moderate fine and medium subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; common very fine roots and medium and coarse roots and fine roots; few fine tubular pores; 15 percent rounded ignimbrite gravel; violent effervescence; moderately alkaline; clear smooth boundary. Lab sample # 98P02483.

Bn2--36 to 69 centimeters (14.2 to 27.2 inches); brown (7.5YR 5/3) gravelly loam, brown (7.5YR 4/3), moist; weak medium and coarse subangular blocky parts to weak fine and medium subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; common very fine and fine roots; few fine tubular and common fine interstitial pores; 20 percent rounded ignimbrite gravel; violent effervescence; moderately alkaline; clear smooth boundary. Lab sample # 98P02484.

Cn1--69 to 91 centimeters (27.2 to 35.8 inches); reddish brown (5YR 5/3) extremely gravelly loamy sand, reddish brown (5YR 4/3), moist; single grain; soft, very friable, nonsticky, nonplastic; common very fine and fine roots; many fine interstitial pores; 60 percent rounded ignimbrite gravel and 10 percent subrounded ignimbrite cobbles; strong effervescence; moderately alkaline; gradual wavy boundary. Lab sample # 98P02485.

Cn2--91 to 132 centimeters (35.8 to 52.0 inches); reddish brown (5YR 5/3) extremely gravelly coarse sandy loam, reddish brown (5YR 4/3), moist; single grain; loose, very friable, nonsticky, nonplastic; few very fine and fine roots; many fine interstitial pores; 75 percent rounded ignimbrite gravel and 10 percent subrounded ignimbrite cobbles; strong effervescence; slightly alkaline; abrupt wavy boundary. Lab sample # 98P02486.

Cn3--132 to 175 centimeters (52.0 to 68.9 inches); reddish brown (5YR 5/3) extremely gravelly coarse sandy loam, reddish brown (5YR 4/3), moist; single grain; loose, very friable, nonsticky, nonplastic; few very fine and fine roots; many fine interstitial pores; 50 percent rounded ignimbrite gravel, 5 percent subrounded ignimbrite cobbles, and 10 percent subrounded ignimbrite stones; few discontinuous white (10YR 8/1) calcium carbonate coats on rock fragments; strong effervescence; slightly alkaline; abrupt smooth boundary. Lab sample # 98P02487.

2Crk--175 to 203 centimeters (68.9 to 79.9 inches); gray (10YR 6/1) bedrock; massive; fractures are greater than 10 cm apart; few very fine and fine roots in cracks; common fine and medium irregular white (10YR 8/1) calcium carbonate masses in cracks; violent effervescence. Lab sample # 98P02488.

*** Primary Characterization Data ***

(Brewster, Texas)

Pedon ID: 95TX043021

Print Date: Jun 27 2017 10:31AM

Sampled as : Rockpens ; Loamy-skeletal, mixed, superactive, thermic Sodic Ustic Haplocambid
Revised to correlated: Rockpens ; Loamy-skeletal, mixed, superactive, thermic Sodic Ustic Haplocambids

SSL - Project CP98TX119 BREWSTER COUNTY
- Site ID S1995TX043021 Lat: 29° 47' 6.00" north Long: 103° 43' 54.00" west MLRA: 42
- Pedon No. 98P0429
- General Methods 1B1A, 2A1, 2B

United States Department of Agriculture
Natural Resources Conservation Service
National Soil Survey Center
Soil Survey Laboratory
Lincoln, Nebraska 68508-3866

Layer	Horizon	Orig Hzn	Depth (cm)	Field Label 1	Field Label 2	Field Label 3	Field Texture	Lab Texture
98P02482	A	A	0-8				SL	SL
98P02483	Bn1	BN1	8-36				L	L
98P02484	Bn2	BN2	36-69				L	SL
98P02485	Cn1	CN1	69-91				LS	COSL
98P02486	Cn2	CN2	91-132				SL	COSL
98P02487	Cn3	CN3	132-175				SL	COSL
98P02488	2Crk	2Crk	175-203					SIC

PSDA & Rock Fragments

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-
					(- - - - - Total - - - - - -)			(- - Clay - - -)		(- - - - Silt - - - - -)		(- - - - - - - - - - - - - Sand - - - - - - - - - - - - -)					(Rock Fragments (mm))				
				Lab Text-ure	Clay < .002	Silt .002 -.05	Sand .05 -2	Fine < .0002	CO_3 < .002	Fine .002 -.02	Coarse .02 -.05	VF .05 -.10	F .10 -.25	M .25 -.50	C .5 -1	VC 1 -2	(- - - - - - - - Weight - - - - - - - -) 2 -5	5 -20	20 -75	.1- 75	>2 mm wt % whole soil
Layer	Depth (cm)	Horz	Prep		(- % of <2mm Mineral Soil -)												(- - - - - - - % of <75mm - - - - - -)				
				3A1a1a	3A1a1a	3A1a1a	3A1a1a		3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3B1	3B1	3B1		
98P02482	0-8	A	S	sl	12.3	21.1	66.6			11.3	9.8	14.2	19.4	15.8	12.5	4.7	6	9	--	60	15
98P02483	8-36	Bn1	S	l	23.6	31.2	45.2		3.8	19.4	11.8	15.9	13.6	7.3	6.1	2.3	4	5	1	36	10
98P02484	36-69	Bn2	S	sl	16.4	23.8	59.8		2.4	14.9	8.9	12.2	13.6	13.4	12.6	8.0	8	18	25	74	54
98P02485	69-91	Cn1	S	cosl	10.2	11.7	78.1		0.7	9.2	2.5	3.8	10.3	22.1	28.9	13.0	8	15	48	93	74
98P02486	91-132	Cn2	S	cosl	9.3	11.6	79.1			6.4	5.2	3.7	8.2	18.6	27.5	21.1	10	40	30	95	82
98P02487	132-175	Cn3	S	cosl	12.3	9.2	78.5			6.3	2.9	2.0	6.4	25.0	32.6	12.5	9	18	22	88	59
98P02488	175-203	2Crk	S	sic	40.8	49.9	9.3			41.3	8.6	4.3	2.5	1.1	0.7	0.7	19	56	10	87	85

Bulk Density & Moisture

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-
				(Bulk Density)		Cole	(- - - - - - - - - - - Water Content - - - - - - - - - - -)						WRD	Aggst	(- - Ratio/Clay - -)	
				33 kPa	Oven Dry	Whole Soil	6 kPa	10 kPa	33 kPa	1500 kPa	1500 kPa Moist	Ratio AD/OD	Whole Soil	Stabl 2-0.5mm	CEC7	1500 kPa
Layer	Depth (cm)	Horz	Prep	(- - - g cm^{-3} - - -)			(- - - - - - - - - - - - % of < 2mm - - - - - - - - - - - -)						cm^3 cm^{-3}	%		
										3C2a1a		3D1		3F1a1a	8D1	8D1
98P02482	0-8	A	S							6.8		1.018		65	1.49	0.55
98P02483	8-36	Bn1	S							10.4		1.025			1.12	0.44
98P02484	36-69	Bn2	S							8.0		1.021			1.37	0.49
98P02485	69-91	Cn1	S							6.5		1.014			1.84	0.64
98P02486	91-132	Cn2	S							6.3		1.014			2.10	0.68
98P02487	132-175	Cn3	S							7.0		1.015			1.71	0.57
98P02488	175-203	2Crk	S							23.4		1.054			1.20	0.57

*** Primary Characterization Data ***

Pedon ID: 95TX043021 (Brewster, Texas) Print Date: Jun 27 2017 10:31AM

Sampled As : Rockpens Loamy-skeletal, mixed, superactive, thermic Sodic Ustic Haplocambid

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 98P0429

Carbon & Extractions

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-	-19-
				(- - - - - Total - - - - -)			Est	OC	C/N	(- - - Dith-Cit Ext - - -)			(- - - - - - Ammonium Oxalate Extraction - - - - - -)						(- - - Na Pyro-Phosphate - - -)			
	Depth			C	N	S	OC	(WB)	Ratio	Fe	Al	Mn	Al+½Fe	ODOE	Fe	Al	Si	Mn	C	Fe	Al	Mn
Layer	(cm)	Horz	Prep	(- - - - - - - - - - % of <2 mm - - - - - - - - - -)						(- - - - - - - - - - - - - - - - - - % of < 2mm - - - - - - - - - - - - - - - - -)								mg kg^{-1}	(- - - - - - % of < 2mm - - - - -)			
				6A2e	6B4a																	
98P02482	0-8	A	S	0.51	0.056		0.4															
98P02483	8-36	Bn1	S	1.49	0.074		0.6															
98P02484	36-69	Bn2	S	1.33	0.044		0.3															
98P02485	69-91	Cn1	S	0.59	0.046		0.1															
98P02486	91-132	Cn2	S	0.34	0.040		tr															
98P02487	132-175	Cn3	S	0.50			--															
98P02488	175-203	2Crk	S	2.56			--															

1,1,2,3,4,5,6 Analyzed size fraction = <2 mm

CEC & Bases

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-
				(- - - - - - NH_4OAC Extractable Bases - - - - -)								CEC8	CEC7	ECEC		(- - - - Base - - - -)	
								Sum	Acid-	Extr	KCl	Sum	NH_4	Bases	Al	(- Saturation -)	
	Depth			Ca	Mg	Na	K	Bases	ity	Al	Mn	Cats	OAC	+Al	Sat	Sum	NH_4OAC
Layer	(cm)	Horz	Prep	(- - - - - - - - - - - - - - - - - cmol(+) kg^{-1} -)							mg kg^{-1}	(- - - - cmol(+) kg^{-1} - - -)			(- - - - - - - - % - - - - - - - -)		
				6N2i	6O2h	6P2f	6Q2f		6H5a				5A8b			5C3	5C1
98P02482	0-8	A	S	32.1*	1.0	0.4	1.7		--				18.3			100	100
98P02483	8-36	Bn1	S	55.6*	0.5	1.4	0.8						26.4			100	100
98P02484	36-69	Bn2	S	50.9*	0.2	2.4	0.4						22.4			100	100
98P02485	69-91	Cn1	S	44.0*	0.2	3.0	0.4						18.8			100	100
98P02486	91-132	Cn2	S	40.4*	0.2	5.8	0.2		--				19.5			100	100
98P02487	132-175	Cn3	S	41.2*	0.4	11.9	0.5		--				21.0			100	100
98P02488	175-203	2Crk	S	57.1*	1.4	24.3	0.5						49.0			100	100

*Extractable Ca may contain Ca from calcium carbonate or gypsum., CEC7 base saturation set to 100.

*** Primary Characterization Data ***

Pedon ID: 95TX043021 (Brewster, Texas) Print Date: Jun 27 2017 10:31AM

Sampled As : Rockpens Loamy-skeletal, mixed, superactive, thermic Sodic Ustic Haplocambid

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 98P0429

Salt

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-	-19-	-20-
				(Water Extracted From Saturated Paste)																	1:2		
Layer	Depth (cm)	Horz	Prep	Ca	Mg	Na	K	CO_3	HCO_3	F	Cl	PO_4	Br	OAC	SO_4	NO_2	NO_3	H_2O	Total Salts	Elec Cond	Elec Cond	Exch Na	SAR
				(- mmol(+) L^{-1} -)				(- mmol(-) L^{-1} -)										(- % -)		(- dS m^{-1} -)		%	
				6N1d	6O1d	6P1d	6Q1d	6I1b	6J1b	6U1c	6K1e				6L1e	6W1c	6M1e	8A	8D5	8A3a	4F1a1a1		5E
98P02482	0-8	A	S																		0.19	2	
98P02483	8-36	Bn1	S																		0.23	5	
98P02484	36-69	Bn2	S	8.5	0.1	6.4	tr	--	3.8	tr	3.2				3.7	2.7	1.6	34.0	tr	1.50	0.37	10	3
98P02485	69-91	Cn1	S	15.2	0.1	10.9	tr	--	3.5	--	6.6				2.4	0.4	13.9	27.6	0.1	2.75	0.55	14	4
98P02486	91-132	Cn2	S	2.8	0.1	16.5	tr	--	3.9	tr	6.7				1.1	0.8	5.3	25.6	tr	1.90	0.40	28	14
98P02487	132-175	Cn3	S	0.3	tr	19.5	--	--	6.2	0.1	8.4				2.9	0.2	0.7	30.5	tr	1.88	0.64	54	47
98P02488	175-203	2Crk	S																		1.05	50	

pH & Carbonates

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-
				(- pH -)						(- Carbonate -) As $CaCO_3$		(- Gypsum -) As $CaSO_4$*$2H_2O$		
Layer	Depth (cm)	Horz	Prep	KCl	$CaCl_2$ 0.01M 1:2	H_2O 1:1	Sat Paste	Oxid	NaF	<2mm	<20mm	<2mm	<20mm	Resist ohms cm^{-1}
										(- % -)				
					4C1a2a	4C1a2a	8C1b			4E1a1a1a1	6E4b	4E2a1a1a1		
98P02482	0-8	A	S		7.9	8.6				1				
98P02483	8-36	Bn1	S		7.8	8.4				8	7			
98P02484	36-69	Bn2	S		7.8	8.3	7.4			9	6			
98P02485	69-91	Cn1	S		7.8	8.2	7.5			4	2	--		
98P02486	91-132	Cn2	S		8.0	8.9	7.8			3	1			
98P02487	132-175	Cn3	S		8.4	9.5	8.3			5	3	--		
98P02488	175-203	2Crk	S		8.9	9.1				22	4	--		

Clay Mineralogy (<.002 mm)

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-
				X-Ray						Thermal			Elemental							EGME	Inter
													SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Na_2O	Retn	preta
	Depth		Fract	7A2i																	tion
Layer	(cm)	Horz	ion	(- peak size -)						(- % -)			(- % -)							mg g^{-1}	
98P02483	8.0-36.0	Bn1	tcly	MT 3	CA 3	QZ 2	ZE 1														
98P02485	69.0-91.0	Cn1	tcly	MT 2	CA 2	QZ 2	ZE 1														
98P02487	132.0-175.0	Cn3	tcly	MT 3	ZE 2	QZ 2	CA 2														
98P02488	175.0-203.0	2Crk	tcly	MT 4	VR 2	QZ 2															

FRACTION INTERPRETATION:

tcly - Total Clay <0.002 mm

MINERAL INTERPRETATION:

CA Calcite MT Montmorillonite QZ Quartz VR Vermiculite ZE Zeolite

RELATIVE PEAK SIZE: 5 Very Large 4 Large 3 Medium 2 Small 1 Very Small 6 No Peaks

*** Primary Characterization Data ***

Pedon ID: 95TX043021 | (Brewster, Texas) | Print Date: Jun 27 2017 10:31AM

Sampled As : Rockpens | Loamy-skeletal, mixed, superactive, thermic Sodic Ustic Haplocambid

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 98P0429

Sand - Silt Mineralogy (2.0-0.002 mm)				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-
						X-Ray					Thermal					Optical				EGME	Inter
													Tot Re			Grain Count				Retn	preta
	Depth		Fract													7B1a2					tion
Layer	(cm)	Horz	ion	(- - - - - - - - peak size				- - - - - - - - -)	(- - - - - - - - %			- - - - - - - - - -)	(- %					- - - - - - - - - - - - - - - - - -)	mg g^{-1}	
98P02483	8.0-36.0	Bn1	fs										24	AR 33	QZ 15	FK 14	FP 13	FE 7	ZE 7		
														GS 5	CA 2	CB 2	OP 1	PR 1	CD 1		
														FZ tr	MS tr	BT tr	ZR tr	HN tr			
98P02485	69.0-91.0	Cn1	fs										25	AR 35	FK 20	QZ 15	FP 13	FE 6	ZE 4		
														OP 3	GS 1	CA 1	CD 1	CB 1	PR 1		
														TM tr							
98P02488	175.0-203.0	2Crk	csi										13	CA 55	CB 14	QZ 9	FK 9	FP 4	AR 4		
														CD 3	FE 1	OP tr	AP tr	BT tr	ZE tr		
														BY tr	MS tr	HN tr	PR tr	ZR tr	GN tr		
														TM tr							

FRACTION INTERPRETATION:

csi - Coarse Silt 0.02-0.05 mm | fs - Fine Sand 0.1-0.25 mm

MINERAL INTERPRETATION:

AP Apatite	AR Weatherable Aggregates	BT Biotite	BY Beryl	CA Calcite
CB Carbonate Aggregates	CD Chert (Chalcedony	FE Iron Oxides (Goethite	FK Potassium Feldspar	FP Plagioclase Feldspar
FZ Feldspathoids	GN Garnet	GS Glass	HN Hornblende	MS Muscovite
OP Opaques	PR Pyroxene	QZ Quartz	TM Tourmaline	ZE Zeolite
ZR Zircon				

Rockpens: Loamy-skeletal, mixed, superactive, thermic Sodic Ustic Haplocambids

The slope gradients for Rockpens range from 1 to 3 percent. This component is located on late-Pleistocene stream terraces, and formed in alluvium derived mainly from tuffs of the Duff, Pruett, and Devils Graveyard Formations, and the Mitchell Mesa ignimbrite (welded tuff). Ignimbrite gravel, cobbles, and stones cover 35 to 95 percent of the surface. Vegetation is mainly creosotebush, Spanish dagger, and fluffgrass (Figure 45).

The Munsell color and the depth of the A horizon (0 to 8 centimeters [0.0 to 3.1 inches]) do not meet the requirements for a mollic epipedon, therefore the epipedon is ochric.

A cambic horizon can be found between the depths of 8 to 69 centimeters (3.1 to 27.2 inches) ((Bn1 and Bn2 horizons), based on the evidence of presence of soil structure and a higher clay content than underlying and overlying horizons.

This soil has a sodic feature, due to a sodium adsorption ratio (SAR) of greater than 13 in a horizon at least 25 centimeters (9.8 inches) thick within 100 centimeters (39.3 inches) of the surface (Cn2 horizon).

There is a paralithic contact at 175 centimeters (68.9 inches), the upper boundary of the 2Crk horizon. Paralithic materials of moderately cemented bedrock of the Duff and Pruett Formations can be found in the zone from 175 to 200 centimeters (68.9 to 78.7 inches). The 2Crk horizon has fine and medium, irregular carbonate masses in cracks. Gypsum crystals can also occur in fractures.

Common roots are described to a depth of 91 centimeters (35.8 inches). Below 91 centimeters (35.8 inches), the occurrence of roots decreases to few. This difference in root density may be due a couple of factors. First, there is a change in soil horizon textures from loam, to sandy loam and loamy sand. Second, the rock fragment volume increases from gravelly to extremely gravelly at this same depth. The gravelly loam is able to store more water than the underlying horizons, which may allow plants to expand their root system. At 175 centimeters (68.9 inches) is a paralithic contact, which is root-restrictive. The zeolitic mineralogy of this component also increases the available water capacity, thereby increasing the plant available water in the soil.

The particle-size control section is from 25 to 100 centimeters (9.8 to 39.3 inches). The CEC activity class is superactive, based on a CEC to clay ratio of 1.56.

Figure 45. Strath terrace landscape with Rockpens forming from alluvium derived from tuff. Creosotebush is seen with ignimbrite gravel covering most of surface.

Stop 7 – Beewon Soil

Banded Vegetation, Clay Loam Pediment Ecological Site, Gravelly Clay Loam Pediment Ecological Site

Print Date: Jun 29 2017

Description Date: Mar 2 1995

Describer: Lynn Loomis, Jerry Rives, Alan Terrell

Site ID: S1995-TX622-004

Pedon ID: S1995-TX622-004

Lab Source ID: KSSL

Lab Pedon #: 98P0417

Soil Name: Beewon

Classification: Loamy-skeletal, mixed, superactive, thermic Ustic Calciargids

Country: United States

State: Texas

County: Brewster

MLRA: Southern Desertic Basins, Plains, and Mountains

Soil Survey Area: Brewster County, Texas (Main Part)

Quad Name: Straddlebug Mountain, Texas

Std Latitude: 29.8349800

Std Longitude: -103.6818750

Latitude: 29 deg 50 min 5.93 sec north

Longitude: 103 deg 40 min 54.75 sec west

Datum: WGS84

UTM Zone: 13

UTM Easting: 627346 meters

UTM Northing: 3301229 meters

Existing Vegetation: creosote bush, mariola, purple pricklypear

Parent Material: zeolitic gravelly pedisediment derived from tuff over carbonatic gravelly alluvium derived from igneous and sedimentary rock over zeolitic gravelly alluvium derived from ignimbrite

Geomorphic Setting: pediment on piedmont slope

Particle-Size Control Section: 13 to 46 cm.

Diagnostic Features: ochric epipedon 0 to 13 cm.
argillic horizon 13 to 46 cm.
calcic horizon 30 to 175 cm.

Slope (%)	Elevation (meters)	Aspect (deg)	MAAT (C)	MSAT (C)	MWAT (C)	MAP (mm)	Frost-Free Days	Drainage Class	Slope Length (meters)	Upslope Length (meters)
0.6	1,144.3	180	17.9			331		well		

Beewon

A--0 to 13 centimeters (0.0 to 5.1 inches); brown (7.5YR 5/3) gravelly loam, brown (7.5YR 4/3), moist; weak medium and coarse subangular blocky parts to weak fine and medium subangular blocky structure; weak thin platy structure in the upper 1 inch; slightly hard, friable, slightly sticky, slightly plastic; common very fine and fine roots throughout; 22 percent subangular ignimbrite gravel; violent effervescence; clear smooth boundary.

Bt--13 to 30 centimeters (5.1 to 11.8 inches); reddish brown (5YR 5/3) extremely gravelly sandy clay loam, reddish brown (5YR 4/3), moist; weak fine and medium subangular blocky structure; hard, friable, moderately sticky, moderately plastic; common very fine and fine roots throughout; 10 percent prominent white (10YR 8/1), dry, carbonate coats on rock fragments and 40 percent distinct clay films on rock fragments; 42 percent subrounded ignimbrite gravel, 22 percent subrounded ignimbrite coarse gravel, and 10 percent subrounded ignimbrite cobbles; strong effervescence; clear smooth boundary.

Btk--30 to 46 centimeters (11.8 to 18.1 inches); reddish brown (5YR 5/4) very gravelly clay, reddish brown (5YR 4/4), moist; weak fine and medium subangular blocky structure; hard, very firm, very sticky, very plastic; common very fine and fine roots throughout; 30 percent distinct white (10YR 8/1), dry, carbonate coats on rock fragments; 2 percent carbonate threads and 5 percent medium lime masses; 34 percent subrounded igneous gravel and 10 percent subrounded igneous cobbles; violent effervescence; abrupt smooth boundary.

2Bk1--46 to 81 centimeters (18.1 to 31.9 inches); pink (5YR 7/3) very gravelly silt loam, light reddish brown (5YR 6/3), moist; weak fine and medium subangular blocky parts to weak fine subangular blocky structure; hard, firm, slightly sticky, slightly plastic; extremely high excavation difficulty; very few very fine roots; 70 percent prominent white (10YR 8/1), dry, carbonate coats on rock fragments; 80 percent medium spherical white (10YR 8/1) lime masses; 40 percent subrounded ignimbrite gravel, 18 percent subrounded ignimbrite cobbles, and 5 percent subrounded ignimbrite stones; violent effervescence; clear wavy boundary. Carbonate masses may be weathered tuff fragments.

2Bk2--81 to 102 centimeters (31.9 to 40.2 inches); pinkish white (5YR 8/2) extremely gravelly silt loam, pink (5YR 7/3), moist; weak medium and coarse subangular blocky structure; hard, firm, slightly sticky, slightly plastic; extremely high excavation difficulty; very few very fine roots; 70 percent prominent white (10YR 8/1), dry, carbonate coats on rock fragments; 80 percent medium spherical white (10YR 8/1) lime masses; 75 percent subrounded ignimbrite gravel, 10 percent subrounded ignimbrite cobbles, and 2 percent subrounded ignimbrite stones; violent effervescence; clear smooth boundary. Carbonate masses may be weathered tuff fragments.

2Bk3--102 to 122 centimeters (40.2 to 48.0 inches); pinkish white (5YR 8/2) extremely cobbly silt loam, light reddish brown (5YR 6/3), moist; weak medium and coarse subangular blocky structure; hard, firm, slightly sticky, slightly plastic; extremely high excavation difficulty; very few very fine roots; 70 percent prominent carbonate coats on rock fragments; 80 percent medium spherical white (10YR 8/1) lime masses; 20 percent subrounded ignimbrite gravel, 60 percent subrounded ignimbrite cobbles, and 5 percent subrounded ignimbrite stones; violent effervescence; abrupt smooth boundary. Lime masses may be weathered tuff fragments.

3Btk1--122 to 175 centimeters (48.0 to 68.9 inches); pinkish gray (5YR 6/2) extremely gravelly loam, reddish brown (5YR 5/3), moist; weak medium and coarse subangular blocky parts to weak fine subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; extremely high excavation difficulty; very few very fine roots; 30 percent distinct white (10YR 8/1), dry, carbonate coats on rock fragments and 65 percent distinct, dry, clay films on rock fragments and 80 percent distinct, dry, clay films on ped faces; 20 percent medium and coarse spherical white (10YR 8/1) lime masses throughout; 60 percent subrounded ignimbrite gravel and 10 percent subrounded ignimbrite cobbles; noneffervescent; gradual smooth boundary. Carbonate masses may be weathered tuff fragments.

3Btk2--175 to 200 centimeters (68.9 to 78.7 inches); pinkish gray (5YR 6/2) very gravelly sandy loam, reddish brown (5YR 4/3), moist; weak medium and coarse subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; extremely high excavation difficulty; very few very fine roots; 30 percent distinct white (10YR 8/1), dry, slickensides (pedogenic) on rock fragments and 65 percent distinct clay films on rock fragments and 80 percent distinct clay films on ped faces; 15 percent medium and coarse spherical white (10YR 8/1) lime masses throughout; 40 percent subrounded ignimbrite gravel, 10 percent subrounded ignimbrite cobbles, and 5 percent subrounded ignimbrite stones; noneffervescent. Lime masses may be weathered tuff fragments.

*** Primary Characterization Data ***

Pedon ID: S1995-TX622-004 (Brewster, Texas) Print Date: Jun 27 2017 10:46AM

Sampled as : Beewon ; Loamy-skeletal, mixed, superactive, thermic Ustic Calciargid
Revised to correlated on Apr 2, 2016: Beewon ; Loamy-skeletal, mixed, superactive, thermic Ustic Calciargids

United States Department of Agriculture
Natural Resources Conservation Service
National Soil Survey Center
Soil Survey Laboratory
Lincoln, Nebraska 68508-3866

SSL - Project CP98TX119 BREWSTER COUNTY
- Site ID S1995-TX622-004 Lat: 29° 50' 5.93" north Long: 103° 40' 54.75" west MLRA: 42
- Pedon No. 98P0417
- General Methods 1B1A, 2A1, 2B

Layer	Horizon	Orig Hzn	Depth (cm)	Field Label 1	Field Label 2	Field Label 3	Field Texture	Lab Texture
98P02417	A	A	0-13				L	L
98P02418	Bt	Bt	13-30				CL	SCL
98P02419	Btk	Btk	30-46				C	C
98P02420	Bk1	Bk1	46-81				C	SIL
98P02421	Bk2	Bk2	81-102				SIL	SIL
98P02422	Bk3	Bk3	102-122				SIL	SIL
98P02423	2Bk1	2Bk1	122-175				L	COSL
98P02424	2Bk2	2Bk2	175-203				SL	COSL

PSDA & Rock Fragments

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-
					(- - - - - Total - - - - - -)			(- - Clay - - -)		(- - - - Silt - - - - -)		(- - - - - - - - - - - - Sand - - - - - - - - - - - -)					(Rock Fragments (mm))				
				Lab	Clay	Silt	Sand	Fine	CO_3	Fine	Coarse	VF	F	M	C	VC	(- - - - - - - - Weight - - - - - - - -)				>2 mm
				Text-	<	.002	.05	<	<	.002	.02	.05	.10	.25	.5	1	2	5	20	.1-	wt %
	Depth			ure	.002	-.05	-2	.0002	.002	-.02	-.05	-.10	-.25	-.50	-1	-2	-5	-20	-75	75	whole
Layer	(cm)	Horz	Prep		(- % of <2mm Mineral Soil -)												(- - - - - - - % of <75mm - - - - - -)				soil
				3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3A1a1a	3B1	3B1	3B1		
98P02417	0-13	A	S	l	23.5	30.0	46.5	3.2	1.8	20.4	9.6	8.6	12.6	12.0	8.6	4.7	4	15	10	57	29
98P02418	13-30	Bt	S	scl	29.0	23.1	47.9	7.3	3.2	13.8	9.3	8.5	12.8	11.2	8.6	6.8	11	29	36	85	79
98P02419	30-46	Btk	S	c	47.5	27.6	24.9	10.4	7.5	21.2	6.4	4.6	4.8	4.3	3.8	7.4	14	32	22	75	72
98P02420	46-81	Bk1	S	sil	17.9	69.6	12.5	5.5	4.8	65.9	3.7	1.7	1.8	1.9	2.6	4.5	7	19	60	88	90
98P02421	81-102	Bk2	S	sil	16.4	66.9	16.7		4.0	61.5	5.4	2.2	2.5	2.7	4.1	5.2	8	31	45	86	86
98P02422	102-122	Bk3	S	sil	18.2	58.2	23.6		4.0	51.6	6.6	3.1	4.1	4.9	5.5	6.0	8	25	40	79	92
98P02423	122-175	2Bk1	S	cosl	19.0	28.9	52.1		0.7	22.3	6.6	3.4	4.4	7.1	19.2	18.0	16	29	33	89	81
98P02424	175-203	2Bk2	S	cosl	14.5	20.0	65.5	13.3	0.7	14.1	5.9	3.4	8.3	20.4	21.9	11.5	7	23	42	89	77

Bulk Density & Moisture

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-
				(Bulk Density)		Cole	(- - - - - - - - - - - Water Content - - - - - - - - - - -)						WRD	Aggst		
				33	Oven	Whole	6	10	33	1500	1500 kPa Ratio		Whole	Stabl	(- - Ratio/Clay - -)	
	Depth			kPa	Dry	Soil	kPa	kPa	kPa	kPa	Moist	AD/OD	Soil	2-0.5mm	CEC7	1500 kPa
Layer	(cm)	Horz	Prep	(- - - g cm^{-3} - - -)			(- - - - - - - - - - - - % of < 2mm - - - - - - - - - - - -)						cm^3 cm^{-3}	%		
										3C2a1a		3D1		3F1a1a	8D1	8D1
98P02417	0-13	A	S							9.9		1.028		46	0.87	0.42
98P02418	13-30	Bt	S							10.7		1.031			0.74	0.37
98P02419	30-46	Btk	S							15.5		1.047			0.57	0.33
98P02420	46-81	Bk1	S							5.9		1.016			0.58	0.33
98P02421	81-102	Bk2	S							5.5		1.014			0.63	0.34
98P02422	102-122	Bk3	S							6.1		1.017			0.68	0.34
98P02423	122-175	2Bk1	S							8.6		1.026			1.10	0.45
98P02424	175-203	2Bk2	S							7.6		1.021			1.23	0.52

*** Primary Characterization Data ***

Pedon ID: S1995-TX622-004 (Brewster, Texas) Print Date: Jun 27 2017 10:46AM

Sampled As : Beewon Loamy-skeletal, mixed, superactive, thermic Ustic Calciargid

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 98P0417

Carbon & Extractions

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-	-19-
				(- - - - - Total - - - - -)			Est	OC	C/N	(- - - Dith-Cit Ext - - -)			(- - - - - - Ammonium Oxalate Extraction - - - - - -)						(- - - Na Pyro-Phosphate - - -)			
	Depth			C	N	S	OC	(WB)	Ratio	Fe	Al	Mn	Al+½Fe	ODOE	Fe	Al	Si	Mn	C	Fe	Al	Mn
Layer	(cm)	Horz	Prep	(- - - - - - - - - % of <2 mm - - - - - - - - -)						(- - - - - - - - - - - - - - - - - - % of < 2mm - - - - - - - - - - - - - - - - -)								mg kg^{-1}	(- - - - - - % of < 2mm - - - - -)			
				6A2e	6B4a																	
98P02417	0-13	A	S	1.54	0.079		0.6															
98P02418	13-30	Bt	S	1.51	0.093		0.5															
98P02419	30-46	Btk	S	3.42	0.126		1.0															
98P02420	46-81	Bk1	S	8.14	0.056		--															
98P02421	81-102	Bk2	S	7.76	0.054		--															
98P02422	102-122	Bk3	S	6.73			--															
98P02423	122-175	2Bk1	S	2.53			0.6															
98P02424	175-203	2Bk2	S	1.92			0.1															

[1,2,3,4,5,6,7] Analyzed size fraction = <2 mm

CEC & Bases

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-
				(- - - - - - NH_4OAC Extractable Bases - - - - -)								CEC8	CEC7	ECEC		(- - - - Base - - - -)	
								Sum	Acid-	Extr	KCl	Sum	NH_4	Bases	Al	(- Saturation -)	
	Depth			Ca	Mg	Na	K	Bases	ity	Al	Mn	Cats	OAC	+Al	Sat	Sum	NH_4OAC
Layer	(cm)	Horz	Prep	(- - - - - - - - - - - - - - - - - cmol(+) kg^{-1} - - - - - - - - - - - - - - - - - - -)							mg kg^{-1}	(- - - - cmol(+) kg^{-1} - - -)			(- - - - - - - - % - - - - - - - -)		
				6N2i	6O2h	6P2f	6Q2f						5A8b			5C3	5C1
98P02417	0-13	A	S	56.5*	2.2	0.3	2.3						20.5			100	100
98P02418	13-30	Bt	S	55.6*	0.9	2.6	0.9						21.5			100	100
98P02419	30-46	Btk	S	59.0*	1.7	0.4	1.2						27.1			100	100
98P02420	46-81	Bk1	S	41.9*	0.7	0.4	0.4						10.4			100	100
98P02421	81-102	Bk2	S	41.9*	0.9	0.4	0.3						10.4			100	100
98P02422	102-122	Bk3	S	46.1*	1.2	0.7	0.3						12.4			100	100
98P02423	122-175	2Bk1	S	50.8*	2.1	1.6	0.7						20.9			100	100
98P02424	175-203	2Bk2	S	45.1*	2.3	2.6	0.6						17.9			100	100

*Extractable Ca may contain Ca from calcium carbonate or gypsum., CEC7 base saturation set to 100.

Salt

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-	-19-	-20-
				(- Water Extracted From Saturated Paste -)																	1:2		
																			Total	Elec	Elec	Exch	
	Depth			Ca	Mg	Na	K	CO_3	HCO_3	F	Cl	PO_4	Br	OAC	SO_4	NO_2	NO_3	H_2O	Salts	Cond	Cond	Na	SAR
Layer	(cm)	Horz	Prep	(- - - - - mmol(+) L^{-1} - - - - -)				(- mmol(-) L^{-1} -)										(- - - - % - - - -)		(- - dS m^{-1} - -)		%	
				6N1d	6O1d	6P1d	6Q1d	6I1b	6J1b	6U1c	6K1e				6L1e	6W1c	6M1e	8A	8D5	8A3a	4F1a1a1		5E
98P02417	0-13	A	S																		0.20	1	
98P02418	13-30	Bt	S	3.1	0.1	9.7	0.2	--	5.2	tr	3.5				2.5	2.9	0.2	40.5	tr	1.25	0.42	10	8
98P02419	30-46	Btk	S	26.3	1.3	0.5	0.5	--	2.0	--	3.7				3.7	0.4	17.2	62.3	0.1	2.65	0.99	1	tr
98P02420	46-81	Bk1	S	28.3	1.2	1.1	0.3	--	1.8	--	4.4				1.6	--	22.9	40.0	0.1	3.09	0.79	3	tr
98P02421	81-102	Bk2	S	19.9	1.2	1.7	0.4	--	2.0	--	5.0				1.4	0.2	16.0	34.3	0.1	2.30	0.53	3	1
98P02422	102-122	Bk3	S	15.2	1.2	2.9	0.3	--	1.9	tr	3.8				1.0	--	14.3	34.0	tr	1.87	0.40	5	1
98P02423	122-175	2Bk1	S	8.1	0.9	6.0	0.3	--	1.6	0.1	5.4				1.0	tr	8.3	32.2	tr	1.60	0.33	7	3
98P02424	175-203	2Bk2	S	2.2	0.5	8.0	0.3	--	2.6	0.3	3.4				1.1	tr	4.3	29.0	tr	1.17	0.29	13	7

*** Primary Characterization Data ***

Pedon ID: S1995-TX622-004 | (Brewster, Texas) | Print Date: Jun 27 2017 10:46AM

Sampled As : Beewon | Loamy-skeletal, mixed, superactive, thermic Ustic Calciargid

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 98P0417

pH & Carbonates

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-
				(- - - pH					- - -)	(- - Carbonate - -) As $CaCO_3$		(- - Gypsum - - -) As $CaSO_4$*$2H_2O$		
Layer	Depth (cm)	Horz	Prep	KCl	$CaCl_2$ 0.01M 1:2	H_2O 1:1	Sat Paste	Oxid	NaF	<2mm	<20mm	<2mm	<20mm	Resist ohms cm^{-1}
										(- - - - %			- - - -)	
					4C1a2a	4C1a2a	8C1b			4E1a1a1a1	6E4b	4E2a1a1a1		
98P02417	0-13	A	S		7.9	8.4				8				
98P02418	13-30	Bt	S		7.8	8.6	7.8			9				
98P02419	30-46	Btk	S		7.6	7.8	7.6			20		--		
98P02420	46-81	Bk1	S		7.8	7.9	7.6			70	26	--		
98P02421	81-102	Bk2	S		7.8	7.9	7.7			66	18	--		
98P02422	102-122	Bk3	S		7.8	8.0	7.8			58	26			
98P02423	122-175	2Bk1	S		7.7	8.2	7.8			16	6			
98P02424	175-203	2Bk2	S		7.9	8.6	7.9			15	7			

Clay Mineralogy (<.002 mm)

				-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-
						X-Ray				Thermal						Elemental				EGME	Inter
													SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	K_2O	Na_2O	Retn	preta
	Depth		Fract			7A2i															tion
Layer	(cm)	Horz	ion	(- - - peak size				- - -)	(- - - %			- - -)	(- - -			%			- - -)	mg g^{-1}	
98P02418	13.0-30.0	Bt	tcly	CA 3	MT 2	MI 2	QZ 2	KK 1													
98P02420	46.0-81.0	Bk1	tcly	MT 3	CA 3	MI 2	KK 1	QZ 1													

FRACTION INTERPRETATION:

tcly - Total Clay <0.002 mm

MINERAL INTERPRETATION:

CA Calcite | KK Kaolinite | MI Mica | MT Montmorillonite | QZ Quartz

RELATIVE PEAK SIZE: 5 Very Large | 4 Large | 3 Medium | 2 Small | 1 Very Small | 6 No Peaks

*** Primary Characterization Data ***

Pedon ID: S1995-TX622-004 (Brewster, Texas) Print Date: Jun 27 2017 10:46AM

Sampled As : Beewon Loamy-skeletal, mixed, superactive, thermic Ustic Calciargid

USDA-NRCS-NSSC-Soil Survey Laboratory ; Pedon No. 98P0417

Sand - Silt Mineralogy (2.0-0.002 mm)

Layer	Depth (cm)	Horz	Fraction	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-
				X-Ray (- - - - - - - - peak size - - - - - - - - -)					Thermal (- - - - - - - - % - - - - - - - - - -)				Tot Re (- - - - - -	Optical Grain Count 7B1a2 - - - - - - % - - - - - - -)						EGME Retn mg g^{-1}	Inter preta tion
98P02418	13.0-30.0	Bt	csi										58	QZ 40	FK 15	CA 13	FP 7	FE 6	CD 6		
														OP 4	CB 2	PR 2	PO 1	ZE 1	GN 1		
														GS 1	BT 1	ZR tr	HN tr	BY tr	MS tr		
														TM tr	FF tr						
98P02420	46.0-81.0	Bk1	csi										9	CA 60	CB 19	FK 7	FE 4	QZ 3	FP 2		
														OP 2	PR 1	BT tr	GN tr	SP tr	CD tr		
														PO tr	ZR tr	TM tr	ZE tr	FF tr	HN tr		

FRACTION INTERPRETATION:

csi - Coarse Silt 0.02-0.05 mm

MINERAL INTERPRETATION:

BT Biotite	BY Beryl	CA Calcite	CB Carbonate Aggregates	CD Chert (Chalcedony
FE Iron Oxides (Goethite	FF Foraminifera	FK Potassium Feldspar	FP Plagioclase Feldspar	GN Garnet
GS Glass	HN Hornblende	MS Muscovite	OP Opaques	PO Plant Opal
PR Pyroxene	QZ Quartz	SP Sphene	TM Tourmaline	ZE Zeolite
ZR Zircon				

Beewon: Loamy-skeletal, mixed, superactive, thermic Ustic Calciargids

The slope gradients for Beewon range from 0 to 3 percent, and, similarly to Quadria, can be found on broad pediment surfaces. However, Beewon soils are on older, slighter higher pediments than the pediments where Quadria is found. This component is derived from skeletal alluvium which formed from the tuffaceous materials of Mitchell Mesa ignimbrite, Cottonwood Springs basalt, and the Duff and Pruett Formations.

The Beewon pediment has a gravel veneer surface, consisting of mainly ignimbrite gravel and cobbles. This gravel veneer increases the amount of surface runoff. The vegetation on this pediment occurs in bands, with much higher production values (335 kg/ha/yr) in the vegetated bands compared to the non-banded areas (0 kg/ha/yr). The vegetative banding captures surface runoff up to a certain threshold, with excess runoff going downhill and captured by the next vegetated band. Vegetation is mainly western honey mesquite, mariola, creosotebush, and sideoats grama (Figure 46).

The epipedon does not meet the Munsell color requirements in the A horizon (0 to 13 centimeters [0 to 5.1 inches]) for a mollic epipedon, therefore the epipedon is ochric.

Total clay content does increase from 23.5 percent in the A horizon, to 29.0 percent in the Bt horizon, to 47.5 percent in the Btk horizon. This clay increase does not meet the requirements for an abrupt textural change however, since the clay content does not increase by 20 percent or more (absolute) in adjacent horizons.

An argillic horizon is found from 13 to 46 centimeters (5.1 to 18.1 inches), based on the evidence of clay illuviation as well as meeting the horizon thickness requirement. A calcic horizon exists from 30 to 200 centimeters (11.8 to 78.7 inches), based on 15 percent or more $CaCO_3$ equivalent in all horizons at these depths, in addition to meeting the horizon thickness requirement.

Presence of common roots occurs to a depth of 46 centimeters (18.1 inches). Below 46 centimeters (18.1 inches), the occurrence of roots decreases to few. This difference in root density may be due to a change in soil horizon textures (laboratory determined) from loam, sandy clay loam, and clay, to silt loam and coarse sandy loam. The loam, sandy clay loam, and clay are able to store more water, which may allow plants to expand their root system. The zeolitic mineralogy of this component also increases the available water capacity, thereby increasing the plant available water in the soil.

The particle-size control section is from 13 to 46 centimeters (5.1 to 18.1 inches). The CEC activity class is superactive, based on a CEC to clay ratio of 0.75.

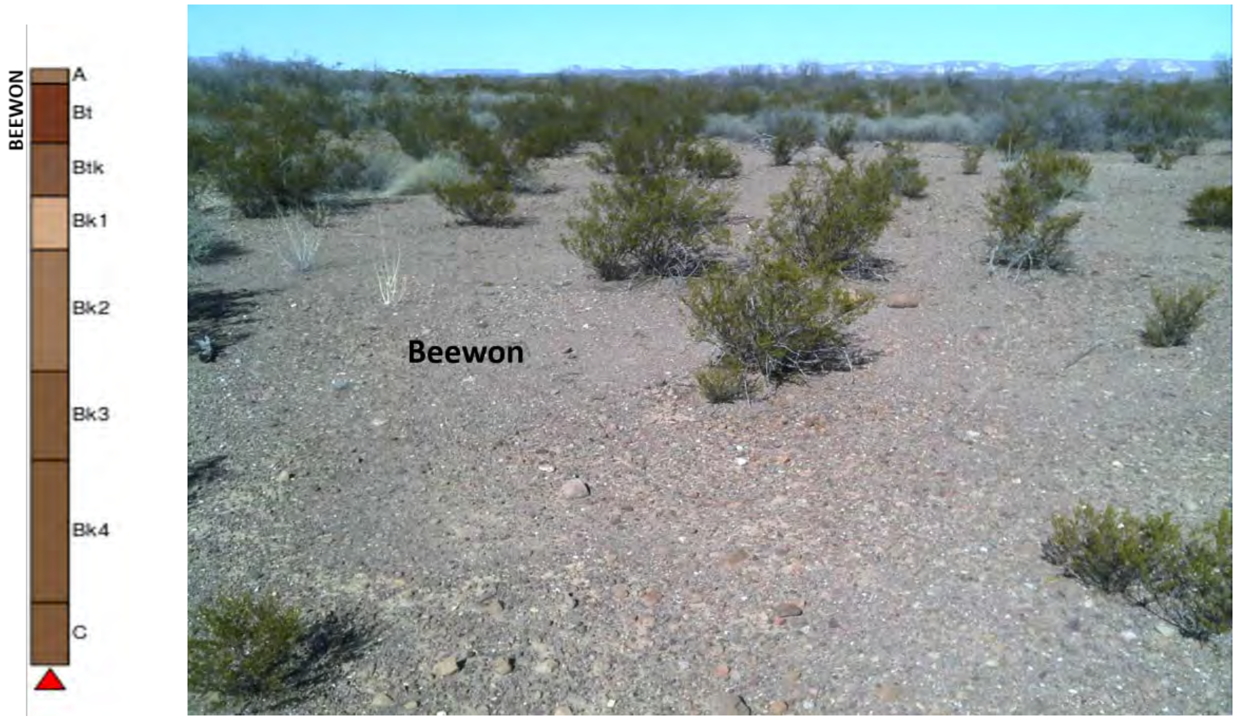

Figure 46. Gravelly pediment landscape with Beewon forming in skeletal alluvium derived from tuff. Sparse creosotebush in foreground, with vegetated banding seen in background.

Modeling Productivity of a Banded Vegetation Pattern: Improving Rangeland Soil Interpretations for Decision Makers

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Marfa Soil Survey Office

Introduction

Banded vegetation patterns occur in the semi-arid fringes of subtropical deserts. Vegetated bands, oriented parallel to elevation contours, alternate at regular intervals with sparsely vegetated interbands. Sparsely vegetated interbands shed a significant portion of precipitation; runoff flows downslope until encountering a vegetated band where the velocity slows and water infiltrates, enhancing the water balance at that point. This resource partitioning concentrates water and consequently vegetation productivity onto a relatively small proportion of the landscape.

In Trans-Pecos Texas (Figure 47), banded vegetation commonly occurs on areas with long slope, low gradient, and deep soil. The Quadria, Beewon, and Musgrave soils, 0 to 30 percent slopes map unit (QBE) encompassing about 10,000 hectares (25,000 acres) in Brewster and Presidio Counties, Texas, supports banded vegetation. The current SSURGO attribute data for QBE provides adequate information regarding dominant soil components, but does not account for the unique ecological sites in the map unit. Though the spatial display of productive vegetation bands has significant value for rangeland managers, map scale (1:24,000) does not allow their delineation. Updating SSURGO attribute data to account for each ecological site would provide increased accuracy for conservation planning, but would deliver no additional spatial detail.

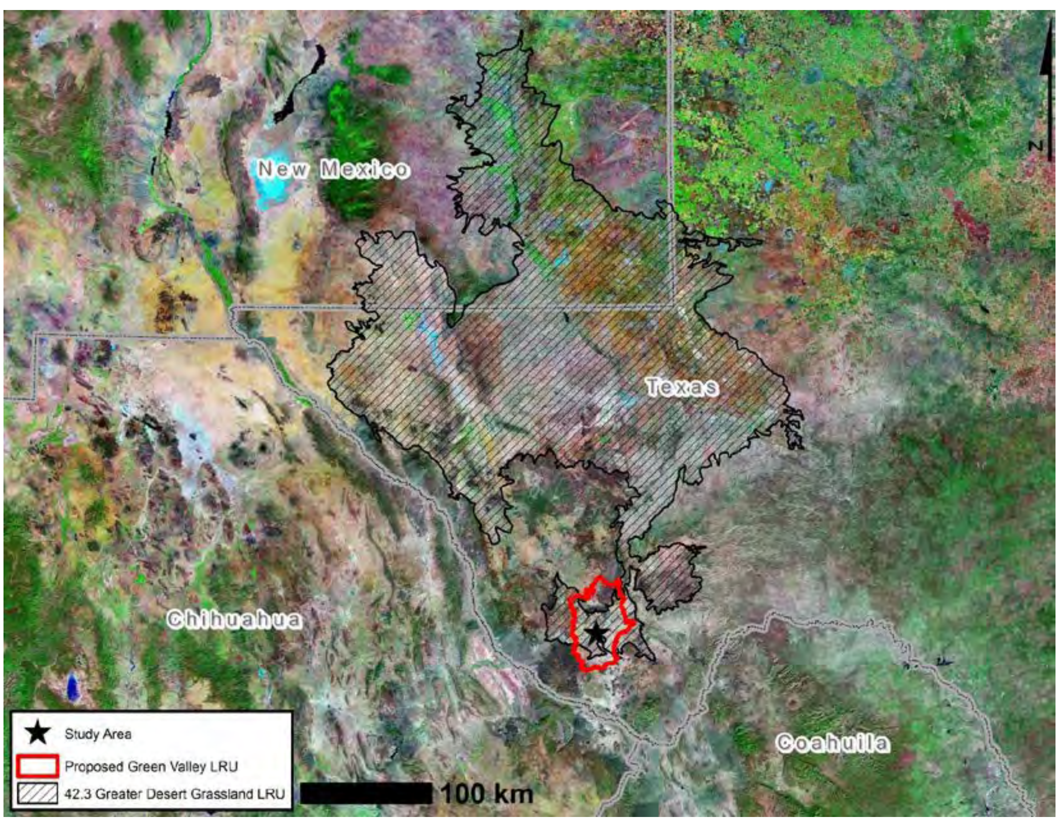

Figure 47. Map of the Trans-Pecos region.

In our knowledge-based approach, the extent and spatial distribution of ecological site-soil components are modeled using ArcSIE software. The method requires knowledge of geomorphic, hydrologic, and ecologic relationships among components and the ability to relate components to environmental covariates. Field investigations guided by directed, constrained, conditioned Latin hypercube sample placement, coupled with opportunistic sampling further develop relationships. In contrast to traditional soil survey methods, our understanding of component-covariate relationships is explicitly archived as a set of rules. The process is iterative and requires repetition of steps and refinement of rules to spatially represent the components and their relationships.

After testing the ArcSIE ruleset, vegetation plots were sampled to quantify productivity. The productivity data, related directly to the modeled components, can be displayed spatially by a weighted-average raster map. This spatial representation provides more realistic data to the end user. Compared to the fuzzy vegetation productivity map, SSURGO overestimates potential forage productivity. Hardened ecological site-soil component raster maps provide spatial detail not available in the vector product and are a valuable tool that range managers can use to improve the long term ecological functionality and profitability of grazing lands.

Study Area

The proposed Green Valley LRU is dominated by soils (Table 7) forming in zeolitic parent materials (residuum, pedisediment, and stream alluvium) derived from tuffaceous bedrock of the Duff, Pruett, and Devils Graveyard Formations (Goldich and Elms, 1949; Table 8). These zeolitic soils have CEC/clay ratios greater than 1.00. Consequently, they possess available water capacity that is higher than similar soils that formed in parent materials with non-zeolitic mineralogy.

One objective of this project was to map and quantify rangeland productivity. Soil map unit descriptions, official series descriptions, and ecological site descriptions do not mention these banded vegetation patterns. Soil survey documents do not mention that significant rangeland production occurs on less than half of the landscape.

Table 7. Classification of component soils within the QBE map unit.

Soil Name	**Family or Higher Taxonomic Class**
Beewon	Loamy-skeletal, mixed, superactive, thermic Ustic Calciargids
Musgrave	Clayey, mixed, superactive, calcareous, hyperthermic, shallow Ustic Torriorthents
Quadria	Fine, mixed, superactive, thermic Ustic Natrargids

Table 8. Genetic factors driving vegetation and soil development within the QBE map unit.

Factor	**Description**
Relief/Time	Nearly level Quaternary-age pediments dissected by Holocene age drainageways
Parent Material	Clayey or gravelly pedisediment with a discontinuous gravel veneer
Climate	Annual air temp: 18 C; annual precipitation: 325 millimeters (12.8 inches); annual water deficit: 650 millimeters (25.6 inches)
Organisms	Chihuahuan Desert flora adapted to water stress

Methods

Site-vegplot-pedon triplets were described, using the methods outlined in (Schoeneberger et al., 2012), at about 90 locations within delineations of QBE. Data on vegetation production was collected from ecological sites and states of the Beewon and Quadria soils by the methods outlined in (Herrick et al., 2009) for representative plots. Productivity values and hardened component maps (Figures 48 and 49) outlined in (Robinson et al., 2016) were used to calculate forage productivity and estimated carrying capacity.

Quarter-quad ortho images from 1996, 2004, 2008, 2010, 2012, and 2015 were downloaded from Texas Natural Resources Information System. Single frame panchromatic aerial photographs of the area taken during 1958, 1974, 1980, and 1991 were downloaded from USGS and georeferenced using ArcGIS.

In areas of Beewon soil, we identified three vegetation classes within two ecological sites: sparsely vegetated and persistently vegetated states within the Clay Loam Pediment ecological site, and a single state of the Gravelly Clay Loam Pediment ecological site. To distinguish vegetation classes, the red spectral band was utilized for 1996-2015, whereas the panchromatic images were utilized for 1958-1991. For each image, digital number thresholds were selected to separate classes.

In areas of Quadria soil, we calculated normalized difference vegetation index (NDVI) for the 2008 ortho image using ERDAS.

Results and Discussion

The vegetation on the QBE map unit exhibits two banded patterns, distinct with respect to certain attributes. These patterns are related to properties of the Beewon and Quadria soils, and are similar in many ways to those described in (McDonald et al., 2009) and (DeBlauwe et al., 2012) in nearby Pecos County.

The banded vegetation patterns of the Beewon and Quadria soils exhibit differences in band-interband contrast, as well as band continuity (Figures 48a, 48b, and Figures 49a, 49b). The ephemerally vegetated state of the Clayey Pediment ecological site is more dynamic than that of the sparsely vegetated state of the Clay Loam Pediment ecological site. In some wet years on the Clayey Pediment ecological site, areas of ephemerally and persistently vegetated states are very similar (Figures 49c and 49d). On the Clay Loam Pediment ecological site, the sparsely vegetated state is situated on the receding downslope margin of persistent bands. Expansion of bands occurs on their upslope margins.

Two ecological sites, Clay Loam Pediment and Gravelly Clay Loam Pediment, occur on Beewon soils (Figures 50, 51, and 52). The Clay Loam Pediment ecological site includes two states: sparsely vegetated and persistently vegetated.

Figure 53 shows the variation through time of vegetation cover in area of Beewon soils. Vegetation cover percentage was rather static from 1958 until 2000. Change in grazing management coupled with relatively high rainfall during the 2000’s (Figure 54) resulted in a significant increase in vegetation cover shown in (Figures 48c and 48d). The famous drought of 2011 reduced cover precipitously. However, by 2015 vegetation had returned to pre-drought levels. Vegetated bands migrated some 10 to 30 meters (33 to 98 feet) upslope from 1958 to 2015. Similar band movement in Pecos County has been documented in (DeBlauwe et al., 2012). From 1958 to 1974 the bands exhibited the most migration. Compared to 1974, band coverage in 2015 increased by about 1.5 times.

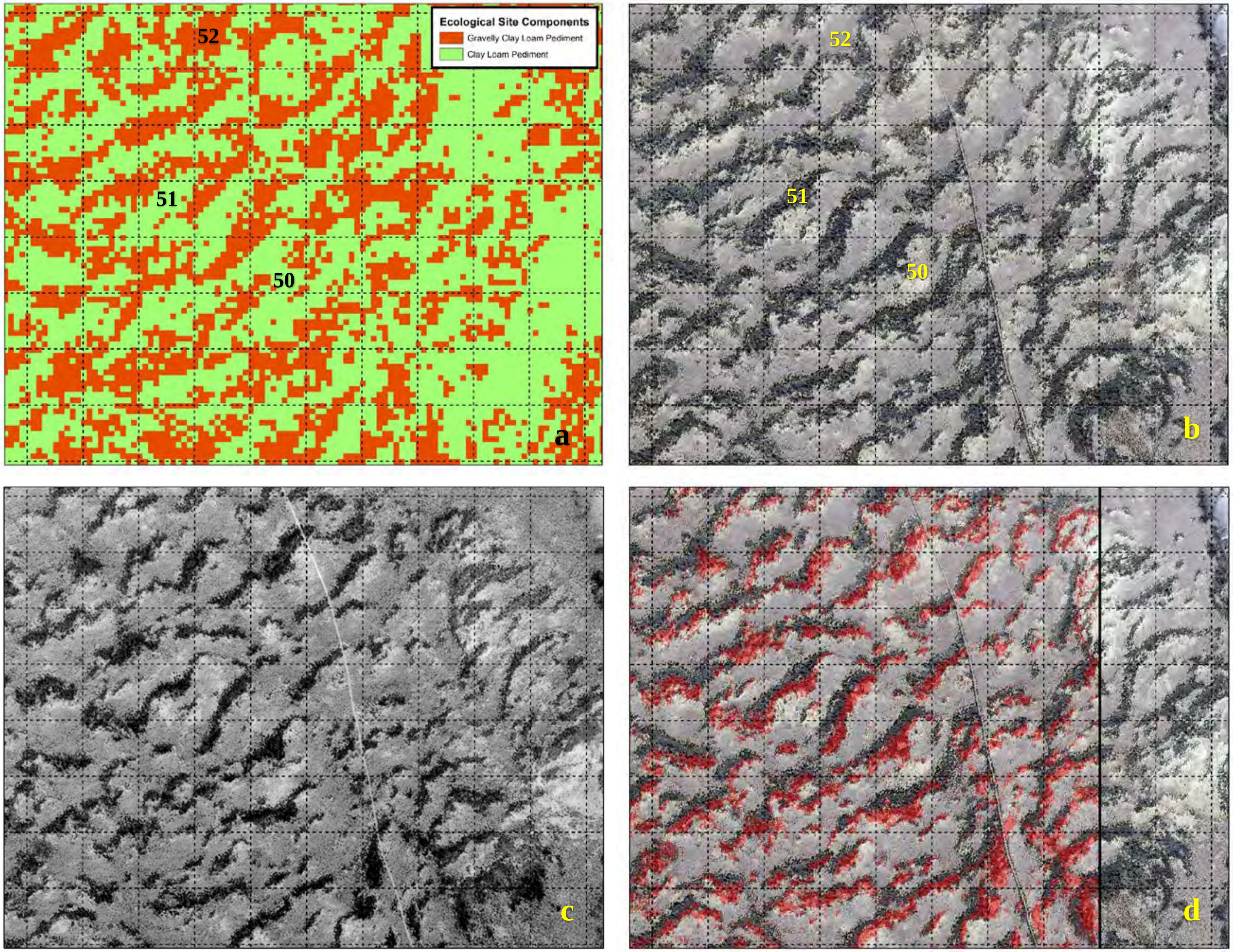

Figure 48. Area of Beewon soils: (a) hardened ecological site component map; (b) January 2015, orthoimage; (c) February 1974, panchromatic image; and (d) January 2015, orthoimage overlaid with persistently vegetated bands (in red) from 1974 image. A 100-m interval dashed reference grid is included. Spatial location of Figures 50, 51, and 52 is labeled on Figures 48a and 48b. North is upward.

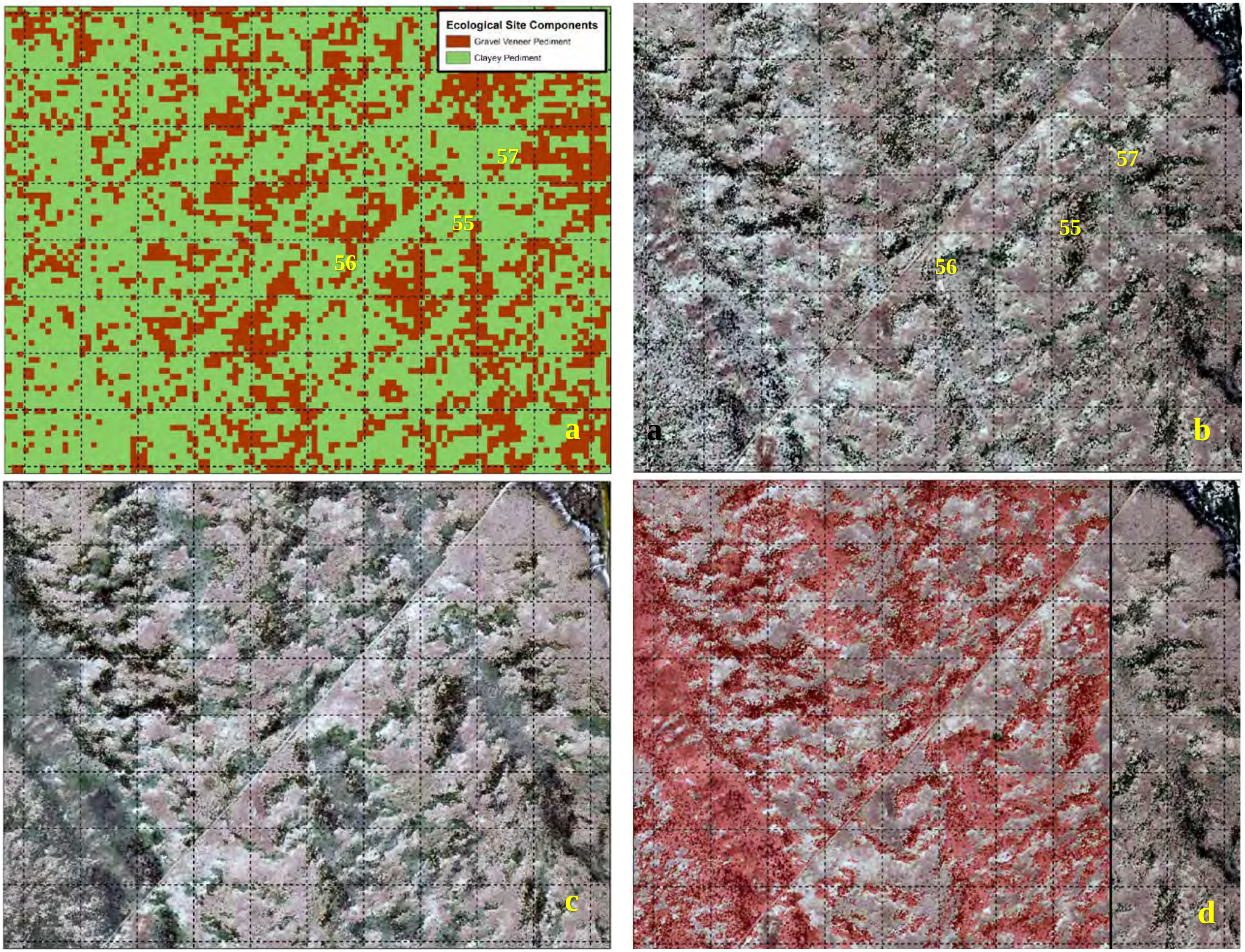

Figure 49. Area of Quadria soils: (a) hardened ecological site component map; (b) October 2014, orthoimage; (c) September 2008, orthoimage; and (d) October 2014, orthoimage overlaid with positive NDVI (in red) from September 2008 orthoimage. A 100-m interval dashed reference grid is included. Spatial position of Figures 55, 56, and 57 labeled on maps. North is upward.

Figure 50. Sparsely vegetated state of the Clay Loam Pediment ecological site with forage productivity of 0 kg/ha/yr.

Figure 51. Persistently vegetated state of the Clay Loam Pediment ecological site with forage productivity of 335 kg/ha/yr.

Figure 52. Gravelly Clay Loam Pediment ecological site with forage productivity of 0 kg/ha/yr.

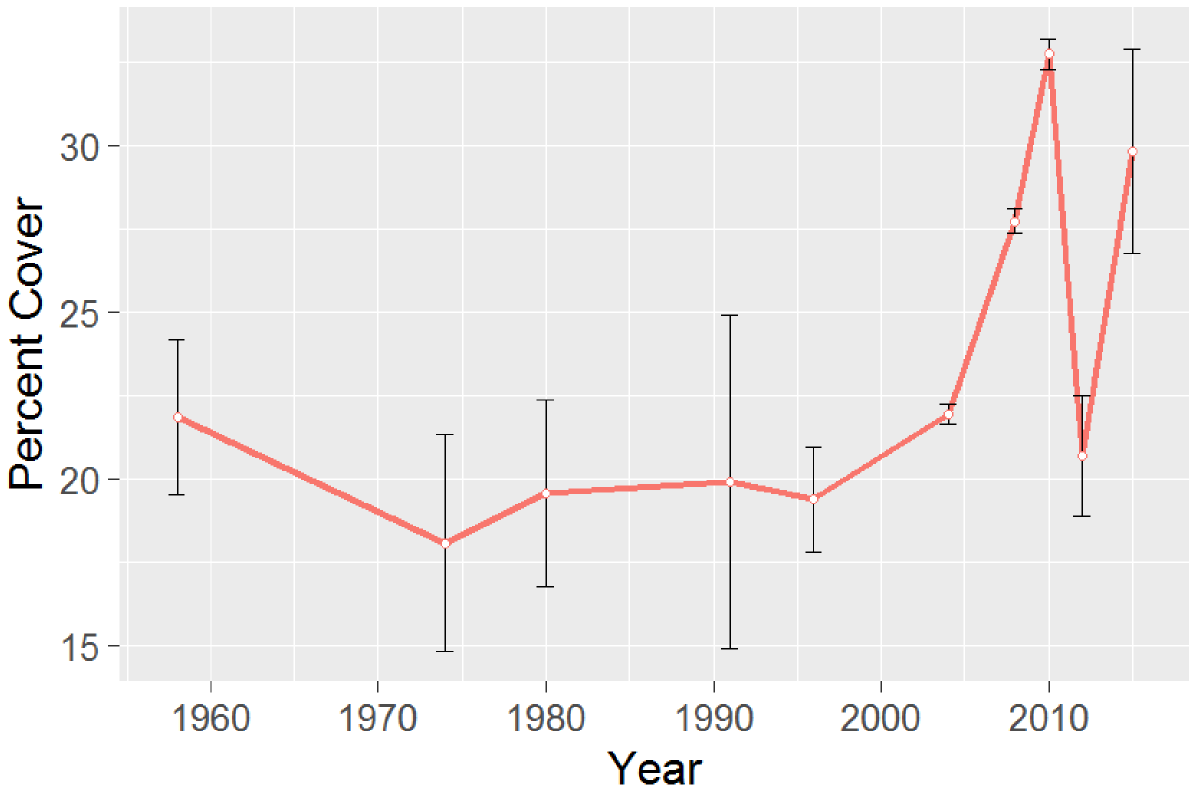

Figure 53. Percent cover of persistent vegetation with time in area of Beewon soils.

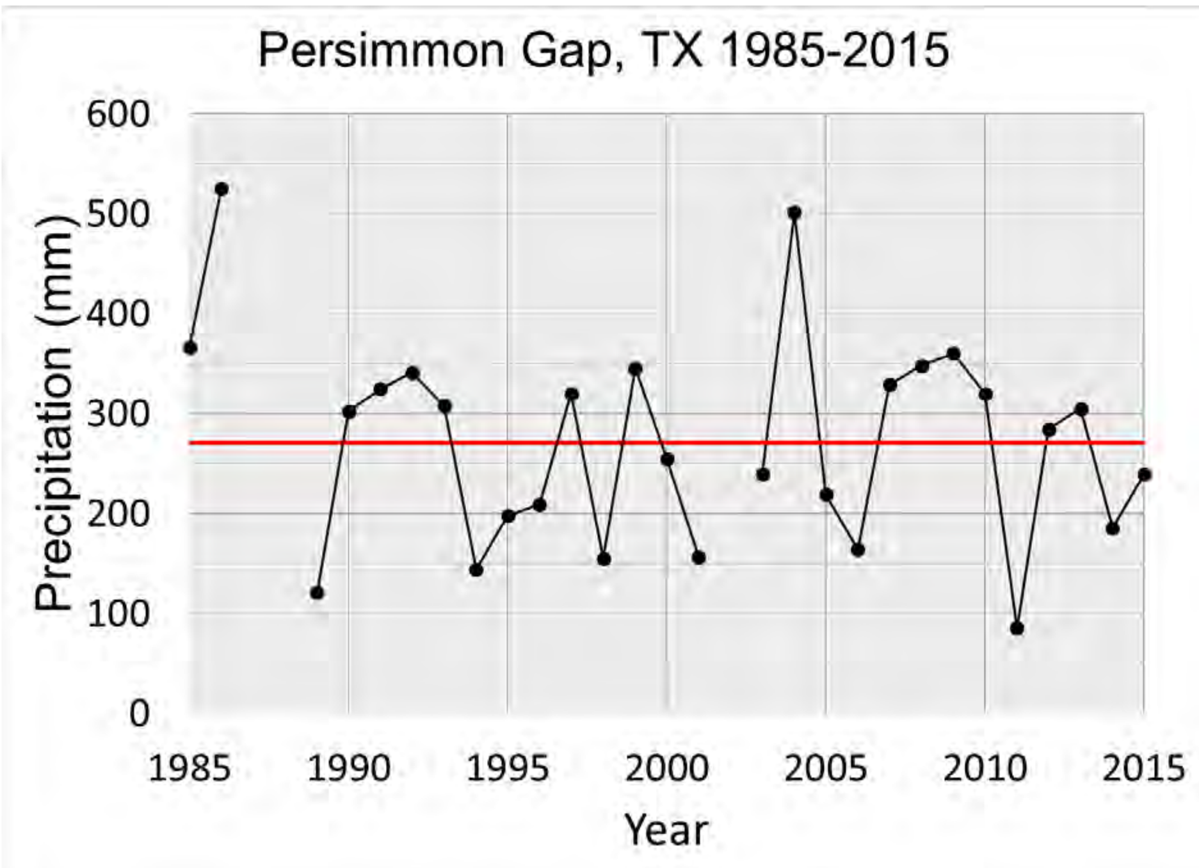

Figure 54. Annual precipitation at Persimmon Gap, Texas, located 250 meters (820 feet) lower in elevation and 50 kilometers (155 miles) east of the study area.

The Clayey Pediment and Gravel Veneer Pediment ecological sites exist on Quadria soils (Figures 55, 56, and 57). Surface fragment cover determines hydrology, site potential, and vegetation dynamics. The Clayey Pediment ecological site consists of two states: ephemerally vegetated and persistently vegetated.

Rasters can portray where and how much of the landscape actually supports productive vegetation. The Gravelly Clay Loam Pediment ecological site and the Gravel Veneer Pediment ecological site have little capability to support permanent vegetation. This fact is not recognized by the current SSURGO data. The QBE SSURGO polygon map does not portray the spatial variability of vegetation production.

Annual forage productivity among ecological sites and states in areas of Beewon soils ranged from 0 kg/ha/yr on the Gravelly Clay Loam Pediment ecological site (Figure 52) to 335 kg/ha/yr on persistently vegetated state of the Clay Loam Pediment ecological site (Figure 51). Quadria soils produced from 5 kg/ha/yron on the Gravel Veneer Pediment ecological site (Figure 57) to 680 kg/ha/yr on the persistently vegetated state of the Clayey Pediment ecological site (Figure 56).

Calculating livestock carrying capacity from raster and vector maps yields quite different results. The estimated carrying capacity of a 10,000 hectares (25,000 acres) ranch would be 408 AUY using the vector ecological site map, compared with 58 AUY for Beewon soils and 114 AUY for Quadria soils derived from the hardened raster map (Table 9).

Table 9. Comparison of estimated livestock carrying capacity of a 10,000 hectares (25,000 acres) ranch.

Method	**Forage Productivity (kg/ha/yr)**	**Carrying Capacity (AUY)**
SSURGO	703	408
Beewon	100	58
Quadria	175	114

Figure 55. Ephemerally vegetated state of the Clayey Pediment ecological site with forage productivity of 150 kg/ha/yr.

Figure 56. Persistently vegetated state of the Clayey Pediment ecological site with forage productivity of 680 kg/ha/yr.

Figure 57. Gravel Veneer Pediment ecological site with forage productivity of 5 kg/ha/yr.

Geologic Atlas of Texas Map Unit Descriptions

Qal: alluvium and low terrace deposits along other streams, may include older Quaternary deposits in some areas.

Qf: colluvium and fan deposits, may include older Quaternary deposits in some areas.

Qao: alluvium, colluvium, and caliche on surfaces dissected by modern drainage; pebbles, cobbles, boulders up to 4 feet in size, and sand; unconsolidated to partly consolidated by caliche cement; composed of chert, quartzite, limestone, and volcanic rocks of vesicular, aphanitic, and porphyritic textures.

Ql: landslide deposits; displaced bouldery masses of rock.

Ti: stocks, laccoliths, sills, and dikes. Major rock types, basalt, hawaiite, mugearite, trachyte, quartz trachyte, rhyolite, phonolite, peralkaline rhyolite, latite, trachyandesite, dacite, basalt, and their coarser grained equivalents. K-Ar ages: Solitario-Olivine syenite 26.4 ± 0.5 m.y., late soda rhyolite intrusion 34.3 ± 0.8 m.y., rim sill 36.6 ± 0.8 m.y., West Chinati-stock 31.2 ± 0.6 m.y., Yellow Hill area-32. 7 ± 1.3, 35.0 ± 2.3, 40.1 ± 1.5 m.y.

Tr Rawls Formation: in the Bofecillos Mountains area, from top down consists of conglomerate, sandstone, and tuff; basalt; bolson fill interbedded with above; trachyte; trachyandesite; latite porphyry; trachybasalt porphyry; nonwelded to thoroughly welded crystal-vitric to lithic-vitric, ash-flow tuff; latite porphyry; basalt; trachyandesite; latite porphyry; trachybasalt porphyry; trachyandesite; tuff; latite porphyry; volcanic mudflow; latite; basalt, tuff, sandstone, and conglomerate; and trachybasalt porphyry. In southeastern part of Presidio area, from top down, porphyritic basalt; conglomerate and tuff; trachyandesite; mafic ash-flow tuff; trachyte; trachyandesite; trachybasalt porphyry; trachyandesite; rhyolite ash-flow tuff; basalt. In north-central and northeastern part of Presidio area, from top down, porphyritic basalt; rhyolite ash-flow tuff; sandstone, conglomerate, and tuff, trachyandesite porphyry; trachyandesite; trachybasalt porphyry; basalt; and tuff, sandstone, and conglomerate. In Tascotal Mesa quadrangle, interfingerings of trachybasalt porphyry, dense basalt, volcanic basalt breccia, and trachyandesite. Maximum thickness of formation about 1,200 feet. K-Ar ages, upper Rawls 23.0 ± 0.4, 22.1 ± 0.4; middle Rawls 26.2 ± 0.5 m.y.

Tpe Petan basalt: trachyandesite porphyry, dark greenish gray to brownish gray, maximum thickness 300 feet.

Tta Tascotal Formation: upper part, sandstone, tuffaceous sandstone, and conglomerate; sandstone medium to coarse grained with lenses, beds, and channel fillings of pebble to cobble conglomerate, mostly limestone, some igneous rocks and chert, about half of interval is tuff and sandy tuff. Lower part, tuff, flaggy, slightly calcareous, light colored; some interbeds of tuffaceous, fine-grained sandstone. Thickness of formation up to 800 feet, crops out in Tascotal Mesa and Buck Hill quadrangles and in Presidio area.

Tmm Mitchell Mesa ignimbrite: cliff-forming ash flow, generally non-welded to slightly welded, where more than 30 feet thick pronounced foliation in a broad zone about midway between base and center; in type area porphyritic, phenocrysts of quartz and opalescent sanidine up to 0.2 inch in size in aphanitic, pink to reddish-gray groundmass; weathers dark reddish gray to black; thickness up to 150 feet, also crops out in Bofecillos area and Tascotal Mesa; K-Ar age, 31.5 ± 0.7 m.y. (18 determinations).

Td Duff Formation: chiefly rhyolitic tuff with minor breccia and conglomerate; tuff fine-grained, well indurated, massive, mostly white, light shades of red and yellow common; conglomerate in lenticular beds up to 40 feet thick, crossbedded, dark brown; thickness up to 1,400 feet, crops out in northwestern part of Emory Peak Sheet area; vent area in Paisano Pass area (western part of Fort Stockton sheet).

Tcb Cottonwood Spring basalt: up to nine or more flows; upper part vesicular, amygdaloidal, reddish gray to reddish brown; middle part massive, grayish black to dark greenish black; lower part commonly flow breccia; thickness up to 325 feet, crops out north of Green Valley.

Tpp Potato Hill andesite: in upper part of Pruett Formation, plagioclase phenocrysts up to an inch in length in part in fine-grained, reddish-brown groundmass, in part in coarse-grained, grayish-brown groundmass, upper half flow breccia, lower half massive, vesicular; thickness about 20 to 40 feet, crops out in Crossen Mesa north of Green Valley.

Tps Sheep Canyon basalt: in middle part of Pruett Formation, at least four flows with vesicular tops, fine- to medium-grained, even textured, locally porphyritic, dark greenish black; thickness up to 235 feet, crops out north of Green Valley.

Tpct Crossen trachyte: in lower part of Pruett Formation, massive, porphyritic, stubby feldspar phenocrysts in fine-grained, gray to reddish-brown groundmass, hard, brittle; weathers to rusty-brown pitted surface; thickness about 150 feet, crops out in Crossen Mesa north of Green Valley.

Tpr Pruett Formation: mostly volcanic tuff, some tuffaceous sandstone, conglomerate, breccia, and tuffaceous fresh-water limestone; grayish white, bluish gray, greenish gray, brownish gray, brown, pink, and red, erodes to low rounded hills; Jeff conglomerate at base, mostly well-rounded limestone pebbles and chert of many colors, breccia-conglomerate in upper part mostly composed of igneous rocks cemented by calcareous tuffaceous material, forms resistant ledge up to 40 feet thick; fresh-water limestone, massive, in beds up to 10 feet thick, grayish white to yellowish brown and chocolate brown, fossils are gastropods and algal structures, reaches a thickness of 300 feet.

Tdg Devil's Graveyard Formation: predominately clastic; divided into lower and middle unnamed members and an upper Bandera Mesa Member, each separated by concentrations of channel conglomerates. (Stevens et al., 1984)

Kp Pen Formation: equivalent to upper part of Austin Chalk, mostly clay; upper part sandy with some sandstone beds up to 5 feet thick; middle part, yellow, scattered sandy beds; lower 50 feet, calcareous clay with inch-thick chalk beds, light bluish gray; concretions common throughout, mostly calcareous, some clay-ironstone; weathers yellow to yellowish gray; topographically low; marine fossils throughout; Exogyra ponderosa common; thickness is 219 to 700 feet in Big Bend National Park, 1,000 feet in the Terlingua area, 200 feet in the Bofecillos area, and crops out in the Black Gap area.

Kbse Boquillas Formation: consists of an upper unit, San Vicente Member, Kbs, equivalent to lower part of Austin Chalk, and a lower unit, Ernst Member, equivalent to Boquillas Flags, Kbo. San Vicente Member, not separately mapped, thin to medium bedded, chalky, argillaceous, limestone flags interbedded with gray to yellowish-gray platy marl and soft gray marl; marine megafossils and microfossils abundant; thickness 130 to 400 feet in Big Bend National Park, 274 feet in Black Gap area, crops out widely. Ernst Member, not separately mapped, limestone, siltstone, and clay; limestone, silty ranging to siltstone, flaggy, beds mostly 2 to 5 inches, some up to 18 inches; clay mostly as partings; bluish gray, weathers light yellowish gray to light brownish yellow, blocky from joints; marine megafossils and microfossils common; thickness 277 feet in Black Gap area, 450 feet in Big Bend National Park, 600+ feet in Tascotal Mesa quadrangle, and 1,000 feet in Terlingua area.

Kbd Buda limestone: in Big Bend National Park and eastward divisible into three parts; upper unit, limestone, microgranular, porcelaneous, hard, conchoidal fracture, grayish white, up to 60 feet thick; middle unit, limestone, argillaceous, marly, nodular, weathers to a lumpy surface, grayish white, about 30 feet thick; lower unit, similar to upper unit, about 25 feet thick; thickness of Buda 80 feet in Hood Spring and Santiago Peak quadrangles, and 61 feet in Tascotal Mesa quadrangle.

Kbd Del Rio clay: mostly clay, some interbedded, flaggy, siliceous limestone, friable sandstone, and thin beds of ferruginous clay; clay, soft, bluish to greenish gray, weathers yellow to light brown; thickness up to 180 feet in Terlingua district, 185 feet in western part of Black Gap area, feathers out eastward toward Rio Grande, 70 feet thick in Hood Spring, Santiago Peak, and Tascotal Mesa quadrangles.

Kse Santa Elena limestone: fine-grained to microgranular, massive, beds up to 10 feet thick, some marl interbeds in upper part, rounded chert nodules and silicified rudistids common in more massive beds, light gray to white; weathers dark gray and shades of brown; rudistids and milliolids abundant; forms cliffs; thickness about 500 feet in Santiago Peak area, 740 feet at mouth of Santa Elena Canyon, 943 feet in Black Gap area.

Glossary

Note: Sources derived from National Soil Survey Handbook (NSSH) 629 (USDA NRCS) and Glossary of Geology (Jackson, 1997)

alluvial fan: a low, outspread mass of loose materials and/or rock material, commonly with gentle slopes, shaped like an open fan or a segment of a cone, deposited by a stream (best expressed in semiarid regions) at the place where it issues from a narrow mountain or upland valley; or where a tributary stream is near or at its junction with the main stream. It is steepest near its apex which points upstream and slopes gently and convexly outward (downstream) with a gradual decrease in gradient. GG

alluvial flat: (colloquial: western U.S.A.) a nearly level, graded, alluvial surface in bolsons and semi-bolsons which commonly does not manifest traceable channels, terraces, or flood plain levels. Compare – floodplain step, terrace, valley flat. FFP, GG, & SW. GG

alluvial geomorphic surface: fluvial landforms such as alluvial fans and stream terraces that commonly are formed at climatically induced times of deposition or erosion. (Bull, 1991)

ash fall: airborne ash that falls from an eruption cloud, and the resulting deposit.

ash flow: a turbulent mixture of gas and pyroclastic materials of high temperature ejected explosively from a crater or fissure, that travels swiftly down the slopes of a volcano or along the ground surface. The material in an ash flow, although unsorted, is dominantly of particles of ash size (less than 4 mm in diameter) but generally contains different amounts of lapilli and blocks. (Ross and Smith, 1961)

basalt: (a) in the IUGS classification, a volcanic rock defined modally by Q/(Q+A+P) between 0 and 20 percent or F/(F+A+P) between 0 and 10 percent , P/(A+P) > 65 percent, and M > 35 percent. Because modes are difficult to estimate for these rocks, basalt is also defined in the TAS diagram as rock falling in the area defined b points with SiO2 and alkali coordinates: 45, 0; 45, 5; 52, 0; 52.

(b) a general term for dark-colored mafic igneous rocks, commonly extrusive but locally intrusive (dikes) composed chiefly of calcic plagioclase and clinopyroxene; the fine-grained equivalent of gabbro. Nepheline, olivine, orthopyroxene, and quartz may be present in the CIPW norm but not all simultaneously: nepheline and olivine can occur together as can olivine and orthopyroxene, and orthopyroxene and quartz, but with nepheline does not coexist with orthopyroxene or quartz, nor quartz with nepheline or olivine. (Jackson, 1997)

base level: The theoretical limit or lowest level toward which erosion of the Earth's surface constantly progresses but seldom, if ever, reaches; especially the level below which a stream cannot erode its bed. The general or ultimate base level for the land surface is sea level, but temporary base levels commonly exist locally. GG

constructional: (adjective) Said of a landform that owes its origin, form, position, or general character to depositional (aggradational) processes, such as the accumulation of sediment (e.g., alluvial fan, volcanic cone). Compare – aggradation, destructional, erosional. GG

dike [intrusive rocks] – A tabular igneous intrusion that cuts across the bedding or foliation of the country rock. Compare – sill. GG

epiclastic: pertaining to any clastic rock or sediment other than pyroclastic. Constituent fragments are derived by weathering and erosion rather than by direct volcanic processes. Compare – pyroclastic, volcaniclastic, clastic, detritus. HP

extrusive: (adjective) said of igneous rocks and sediments derived from deep-seated molten matter (magmas), deposited and cooled on the earth's surface (e.g., including lava flows and tephra deposits). Compare – intrusive, volcanic. HP

geomorphic surface: a mappable area of the earth's surface that has a common history; the area is of similar age and is formed by a set of processes during an episode of landscape evolution. A geomorphic surface can be erosional, constructional or both. The surface shape can be planar, concave, convex, or any combination of these. Compare constructional, erosional. (Ruhe, 1956).

igneous rock: rock formed by cooling and solidification from magma, and that has not been changed appreciably by weathering since its formation; major varieties include plutonic and volcanic rocks. Examples: andesite, basalt, granite. Compare – intrusive, extrusive, metamorphic rock. GSST & HP

ignimbrite: the deposit of a pyroclastic flow. The term originally implied dense welding but there is no longer such a restriction, so that the term includes rock types such as welded tuff and non-welded sillar. (Jackson, 1997)

intrusive: denoting igneous rocks derived from molten matter (magmas) that invaded pre-existing rocks and cooled below the surface of the earth. Compare – extrusive. HP

pediment: a gently sloping erosional surface developed at the foot of a receding hill or mountain slope, commonly with a slightly concave-upward profile, that cross-cuts rock or sediment strata that extend beneath adjacent uplands. The erosion surface may be essentially bare bedrock (i.e., rock pediment), or it may be thinly mantled (e.g., 1 to 3 m) with debris (i.e., pediment) such as colluvium, pedisediment, or alluvium that is ultimately in transit from an upland front to basin or valley lowland. In hill-footslope terrain the debris mantle (over an erosional contact) is designated "pedisediment." The term has been used in several geomorphic contexts: pediments may be classed with respect to (a) landscape positions (e.g., intermontane-basin piedmont = apron pediment, or valley-border footslope surfaces (= terrace pediment); (Cooke and Warren, 1973); (b) type of material eroded (e.g., bedrock = rock pediment, or regolith = pediment); or (c) combinations of the above. Compare – rock pediment, piedmont slope, structural bench. SW, HP, RR

porphyritic: said of the texture of an igneous rock in which larger crystals (phenocrysts) are set in a finer-grained ground-mass, which may be crystalline or glassy or both; a rock with such texture. (Jackson, 1997)

pyroclastic: (adjective) pertaining to clastic rock particles produced by explosive, aerial ejection from a volcanic vent. Such materials may accumulate on land or under water. Compare – epiclastic, volcaniclastic, clastic. G.Smith & HP

rhyolite: (a) in the IUGS classification, a volcanic rock defined in the QAPF diagram as having Q/(Q+A+P) between 20 and 60 percent, and in the TAS diagram by a field, extending to higher silica and alkali contents from a vertical line with its lower end at 69 weight percent SiO_2, 8 percent alkali, and a line sloping from 69 SiO_2, 8 alkalis, to 77 SiO_2 percent, 0 alkalis.

(b) a group of igneous rocks, typically porphyritic and commonly exhibiting flow texture with phenocrysts of quartz and alkali feldspar in a glassy to cryptocrystalline groundmass; also any rock in that group; the fine-grained equivalent of granite; rhyolite grades into rhyodacite with decreasing alkali feldspar content and into trachyte with a decrease in quartz. (Jackson, 1997)

sill [intrusive rocks]: a tabular, igneous intrusion that parallels the bedding or foliation of the surrounding sedimentary or metamorphic rock. Compare – dike. GG

strath terrace: a type of stream terrace, formed as an erosional surface cut on bedrock and thinly mantled (e.g., < 3 m) with stream deposits (alluvium), commonly with a gravel lag deposit immediately above the bedrock. SW & GG

stream terrace: one, or a series of platforms in a stream valley, flanking and more or less parallel to the stream channel, originally formed near the level of the stream, and representing the remnants of an abandoned flood plain, stream bed, or valley floor produced during a former state of fluvial erosion or deposition (i.e., currently very rarely or never floods; inactive cut and fill and/or scour and fill processes). Erosional surfaces cut into bedrock and thinly mantled with stream deposits (alluvium) are called "strath terraces." Remnants of constructional valley floors thickly mantled with alluvium are called alluvial terraces. Compare – alluvial terrace, flood-plain step, strath terrace, terrace. HP & SW

syenite: (a) in the IUGS classification, a plutonic rock with Q between 0 and 5, and P/(A+P) between 10 and 35.

(b) a group of plutonic rocks containing alkali feldspar (usually orthoclase, microcline, or perthite), a small amount of plagioclase (less than in monzonite), one or more mafic minerals (especially amphibole), and quartz, if present, only as an accessory; also any rock in that group; the intrusive equivalent of trachyte. With an increase in the quart content, syenite grades into granite. (Jackson, 1997)

trachyte: (a) in the IUGS classification, a volcanic rock defined in the QAPF diagram by Q/Q+A+P between 0 and 5 percent and P/P+A between 10 and 35 percent and in the TAS diagram by a field partly bounded by points with SiO2 and total alkali coordinated: 57.6, 11.7, 61, 13.5, 63.7, and 69.8. The field is bounded at high silica contents by a vertical lie with its lowest end at 69, 8. In addition, normative quartz is < 20 percent. Compare – trachydacite.

(b) a group of fine-grained, generally porphyritic, extrusive rocks having alkali feldspar and minor mafic minerals (biotite, amphibole, or pyroxee) as the main components and possibly a small amount of sodic plagioclase; also any member of that group; the extrusive equivalent of syente; trachyte grades into latite as the alkali feldspar content decreases and to rhyolite with an increase in quartz. (Jackson, 1997)

tuff: a generic term for any consolidated or cemented deposit that is ≥ 50 percent volcanic ash (< 2 mm); various types of tuff can be recognized based on composition: acidic tuff is predominantly composed of acidic particles; basic tuff is predominantly composed of basic particles. SW

tuffaceous: a modifier for normal grain-size rock name (e.g., sandstone) composed by a mixture of pyroclastic and epiclastic debris. (Schmid, 1981)

volcanic: (adjective) pertaining to (a) the deep seated (igneous) processes by which magma and associated gases rise through the crust and are extruded onto the earth's surface and into the atmosphere, and (b) the structures, rocks, and landforms produced. Compare – extrusive, volcaniclastic. HP

volcaniclastic: pertaining to the entire spectrum of fragmental materials with a preponderance of clasts of volcanic origin. The term includes not only pyroclastic materials but also epiclastic deposits derived from volcanic source areas by normal processes of mass movement and stream erosion. Examples: welded tuff, volcanic breccia. HP

zeolite: a generic term for a large group of minerals of white or colorless (sometimes tinted red or yellow by impurities) hydrous aluminosilicates that analogous in composition to feldspars with sodium, calcium, potassium, (rarely barium or strontium) as their chief metals; have a ratio of Al + Si to nonhydrous oxygen of 1:2 and are characterized by their easy and reversible loss of water of hydration and by their ready fusion and swelling when heated under the blowpipe. Zeolites have long been known to occur as well-formed crystals in cavities in basalt. Of more significance is their occurrence as authigenic minerals in the sediments of saline lakes and the deep sea, and especially in beds of tuff. They form during and after burial, generally by reaction of pore waters with solid aluminosilicate materials (e.g., volcanic glass, feldspar, biogenic silica, and clay minerals) (Hay, 1978). Any of the minerals of the zeolite group, including natrolite, heulandite, analcime, chabazite, stillbite, mesolite, scolecite, phillipsite, launonite, mordeinte, cliniptiloiite, erionite, harmotome, and others less important, as well as minerals not yet classified (such as glauconite) or artificial granular sodium aluminosilicates used in the base exchange method of water softening and as gas absorbents or drying agents. The term now includes such diverse compounds as sulfonated organics or basic resins, which act in similar manner to effect either cation or anion exchange.

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